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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement page 23. 4990

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See half-page Advertisement, last and next week.

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See Advertisement, Jan. 14, page 55.

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See Full Page Advt. page 82, Jan. 14.

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See half-page Advertisement page 64, Dec 31.

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Four 4-6-0 PASSENGER LOCOMOTIVES,
Four 2-8-0 FREIGHT LOCOMOTIVES,
Two 0-6-0 SHUNTING LOCOMOTIVES,
for the above Railway.

Conditions of Tender, Drawings and Specifications may be obtained from the Consulting Engineers, Messrs. C. P. SANDBERG, Palace Chambers, 9, Bridge Street, Westminster, on payment of 10s.

Tenders to be delivered to Messrs. C. P. SANDBERG before Twelve Noon on 31st January, 1916. D 388

COUNTY OF LONDON.

The London County Council invites

Tenders for the Purchase of

ONE 3500 Kw. STEAM ALTERNATOR, 6600 volts, 25 periods per second. The set consists of two Engines, one on each side of the Alternator, complete with Condenser and Air Pump.

The Plant, together with Specifications and Drawings, may be viewed at the Council's Generating Station at Greenwich upon production of a permit. Application for permit to view and Form of Tender should be made to the Chief Officer, London County Council Tramways, 62, Finsbury Pavement, E.C. No Tender received at the County Hall after Eleven a.m. on Tuesday, 1st February, 1916, will be considered. The Council does not bind itself to accept any Tender.

JAMES BIRD,
Clerk of the London County Council.
County Hall, Spring Gardens, S.W.
13th January, 1916. D 378

VICTORIAN STATE RAILWAYS.

THE AGENT-GENERAL FOR VICTORIA, AUSTRALIA, invites

Tenders for the Supply

and DELIVERY, at the Port of Melbourne, fully inclusive of Australian Customs Duties, &c., of the following:—

CONTRACT No. 26,111.—FUSE DISTRIBUTION BOXES and FUSES.

Specifications, Conditions of Contract, and Forms of Tender, may be obtained by *bona fide* Tenderers on application at the Offices of the Consulting Engineers, JOHN COATES & COMPANY, Ltd., 115, Victoria Street, London, S.W.

Tenders, accompanied by the preliminary deposit named in the Conditions of Tendering, must be delivered to the Agent-General for Victoria, Melbourne Place, Strand, W.C., not later than Eleven a.m. on Wednesday, 2nd February, 1916, marked "Tender for Fuse Distribution Boxes and Fuses—Contract 26,111."

The Government of Victoria does not bind itself to accept the lowest or any Tender. D 366

PETER McBRIDE,
Agent-General for Victoria.

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

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Steel Axles for Wagons.	Steel Rails & Fishplates.
Straight Axles for Locomotives.	Steel Fishbolts, &c.
Helical Springs.	Cranked Fishplates.
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	Ramps.

Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steel Axles for Wagons," or as the case may be, not later than Eleven o'clock a.m., on Thursday, the 27th January, 1916.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Company's Offices, Secretary.
48, Copthall Avenue, London, E.C.
19th January, 1916. D 420

BIRKENHEAD UNION.

The Guardians of the Birkenhead Union invite

Tenders from Heating and

Hot Water Engineers for the SUPPLY, DELIVERY, and ERECTION at the Union Institution and Infirmary, Derby Road, Tranmere, Birkenhead, of a COMPLETE CENTRALISED HEATING AND HOT WATER SUPPLY PLANT, together with Mains, Connections and Accessories.

Copies of the General Conditions, Specification and Plans, and Forms of Tender may be obtained from the Consulting Engineers, Messrs. SLOAN & LLOYD BARNES, M.I.Mech.E., 34, Castle Street, Liverpool, on payment of a deposit of Two Guineas, (£2 2s.), which deposit will be returned on receipt of a *bona fide* Tender.

Enquiries (if any) should be addressed to the Engineers. Tenderers are requested to furnish a statement of recent similar work performed.

Canvassing the Guardians, directly or indirectly, will be deemed a disqualification.

Tenders, sealed and endorsed "Centralised Heating and Hot Water Supply Plant," and addressed to the undersigned, must be delivered before Twelve o'clock Noon on 14th February, 1916

By Order,
S. H. CARTER,
Clerk to the Guardians.
Poor Law Offices,
Conway Street, Birkenhead. D 377

APPOINTMENTS OPEN.

UNIVERSITY OF LONDON.

NOTICE IS HEREBY GIVEN, that the Senate will proceed to Elect

External Examiners for the

Examinations above Matriculation for the year 1916-17, as follows:—

One in ENGINEERING MATHEMATICS, and One in METALLURGY and ASSAYING.

Particulars of the remuneration and duties can be obtained on application.

Candidates must send in their names to the External Registrar, with any attestation of their qualifications they may think desirable, on or before *Friday, 28th January*, 1916. (It is particularly desired by the Senate that no application of any kind be made to its individual Members).

If testimonials are submitted, three copies at least of each should be sent. Original testimonials should not be forwarded in any case.

GEO. F. GOODCHILD,
External Registrar.
University of London,
S. Kensington, S.W. D 401

Wanted, in July next, an

experienced MINE MANAGER, for the East; preferably with knowledge of gold mining, cyaniding and slime filter treatments.—Address (by letter), stating age, to K. C., care of J. W. VICKERS & Co., Ltd., 5, Nicholas Lane, E.C. D 421

A Country Controlled Estab-

lishment employed on Machine Tools, REQUIRES an Experienced and Practical MANAGER to take charge of the Night Shift of 200.—Apply to nearest LABOUR EXCHANGE, mentioning this paper and No. 175. No one on Government work will be engaged. D 381

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ANALYTICAL CHEMIST; must be an accurate operator and have experience in inorganic analysis of all kinds. The position offers excellent opportunities. Applicants must be ineligible for military service, and should forward particulars of their experience, references, and salary required.—Address, D 404, Offices of ENGINEERING.

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MAN, WANTED, by Marine Engineers in Shanghai. Must have filled similar position before; must be ineligible for Army and not engaged on Government work. Three years' engagement.—Write, detailing experience and qualifications, also age, to nearest LABOUR EXCHANGE, mentioning this paper and No. A 1372. D 425

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Wanted, for Government

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CHIEF TOOL DRAUGHTSMAN,

experienced in milling and drilling jigs, and press-tool work.

It is essential that applicants should have had experience in the manufacture of small accurate parts.

No man on Government work need apply.

Apply, stating age, experience, salary expected, and a reference, to the nearest BOARD OF TRADE LABOUR EXCHANGE, mentioning this paper and No. A 370. D 341

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Draughtsman, Assistant,

WANTED by Shipbuilders as above. Good salary. No person already on Government work will be engaged.—Write to nearest LABOUR EXCHANGE, mentioning this paper and No. A 1371. D 424

Draughtsman, (Ineligible),

thoroughly accustomed to design and construction of mechanical waterworks, filters and softening plants in steel and concrete, also apparatus for chemical treatment. Must also be prepared to assist outdoors in erection, charging, adjustment and manipulation. No person already employed on Government work will be engaged.—Write, with testimonials, to nearest LABOUR EXCHANGE, mentioning this Journal and D 405.

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Draughtsmen (Senior and

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Wanted, for Government

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ASSISTANT TOOL DRAUGHTSMEN.

Experience in milling jigs, drilling jigs, or Cleveland automatics essential.

Applicants should have had good technical training, and preferably experience in the shops.

No man on Government work need apply.

Apply, stating age, experience, salary expected, and a reference, to the nearest BOARD OF TRADE LABOUR EXCHANGE, mentioning this paper and No. A 371. D 342

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Wanted, Immediately, for

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Wanted, for Works in

Swansea district, a thoroughly capable and experienced FOREMAN, to take charge of fitters and other tradesmen on upkeep of running plant. Give full particulars, experience, copies of testimonials, and salary required. No person on Government work will be engaged.—Apply to your nearest LABOUR EXCHANGE, mentioning this Journal and No. A 1049. D 393

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REQUIRED at once, a DRIVER-MECHANIC; preference given to person having knowledge of large Worthington pumping engines and be competent to undertake running repairs. Wages 6/6 per day of 12 hours and house free on Works. No application entertained from persons who are eligible for the Army or Navy. Good references required.—Apply to MANAGER, WEST SURREY WATER COMPANY, Walton-on-Thames. D 415

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several JIG and TOOL MAKERS, also INSTRUMENT MAKERS and TURNERS, willing to learn to Operate and Set-up Cleveland, Gridley, and Brown and Sharpe automatic machines. No person already engaged on Government work will be considered.—Apply, in first case, to the nearest LABOUR EXCHANGE, mentioning this Journal and C 870.

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with Firm (Government Contractors) manufacturing latest types of machinery, oil and gas engines, &c.; moderate premium.—Address, 6521, Offices of ENGINEERING.

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Gentleman (55), good address,

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M. I. Mech. E. (aged 42),

with 14 years' experience in management of large works now employing over 1400 hands (skilled and semi-skilled), on small accurate repetition work, REQUIRES similar POSITION, or as general manager. Used to control of men, and well up in labour problems. Speaks French, and has business ability, as well as thorough practical and technical college training. Disengaged early February.—Address, D 274, Offices of ENGINEERING.

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Technical Assistant Works

Manager (31) DESIRES CHANGE; 16 years' experience electrical and mechanical. Correspondence, supervision, and control of men.—Address, D 383, Offices of ENGINEERING.

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DESIRES permanent EMPLOYMENT, at home or abroad; works at present for contractor. Has been master of different types of steam suction and reclamation dredgers for 11 years; is also well acquainted with bucket-dredging. Speaks Dutch, Italian, a little French, and Malayo.—Address, D 400, Offices of ENGINEERING.

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THE BENDING AND TORSION OF BEAMS OF COMMERCIAL SECTION.

By E. G. RITCHIE, B.Sc., University College, Dundee.

WHEN a beam is subjected to a torque or twisting moment it suffers a torsional strain of the nature of a shear at all sections perpendicular to the axis of twist, deformation being opposed in virtue of the torsional rigidity of the material. The shear stress on an element of any cross-section accompanying this transverse strain is dependent upon the distance of the element from the axis of twist, the most economical section for uniform intensity of stress—in so far as torsion is concerned—being that in which the material is concentrated at the maximum distance from the axis of twist.

An I-section girder, for instance, theoretically offers the same resistance to bending as does a box-girder having the same over-all dimensions, of the same cross-sectional area, and having top and bottom booms of the same thickness as the flanges of the I beam, but it will be readily recognised that the latter offers a much greater resistance to torsion than does the former. The weakness of an I-section beam is, indeed, surprising. Not only is such a beam much more susceptible to twist than one would predict from a casual observation, but its torsional rigidity is very much less than the ordinary theory of torsion indicates, as the following experiments go to show.

Bending:

E denotes the modulus of direct elasticity.
I denotes the moment of inertia about the axis of bending.
W denotes load applied at centre of span.
l denotes span.
δ denotes deflection at centre of span.

Twisting:

C denotes the modulus of rigidity.
J denotes polar moment of inertia about axis of twist.
T denotes torque or twisting moment.
L denotes length over which angle of twist is measured.
θ denotes angle of twist in radians.

In the following investigation, inch-pound units are used throughout.

Mathematical Treatment of the Subject.—(1) The ordinary formulæ relating to the elastic bending of beams are rigorously true, and the deflection of a beam under any system of loading can be calculated accurately by their use, except that deflections due to shear are not taken into account. In all engineering problems relating to beams, the deflection produced by transverse shear is so small as compared with the deflection produced by longitudinal flexure that the former may be, and indeed usually is, neglected.

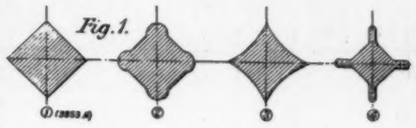


TABLE I.

No.	Type of Beam.	Dimensions.					Moments of Inertia.			Diameter of Circular Section of Equal Area.
		Width.	Depth.	Thickness of Flange.	Thickness of Web.	Area.	Ix.	Iy.	J.	
		in.	in.	in.	in.	sq. in.				in.
1	I	5.01	8.02	0.605	0.30	8.02	91.10	13.10	104.2	3.19
2	Do.	3.01	5.00	0.325	0.20	2.43	3.70	1.20	4.90	1.76
3	Do.	1.75	4.78	0.324	0.19	1.91	6.70	0.26	6.96	1.56
4	Do.	1.66	3.16	0.23	0.17	1.222	1.92	0.177	2.097	1.25
5	Do.	0.99	1.96	0.165	0.22	0.6825	0.336	0.0281	0.3641	0.936
6	Do.	0.76	1.50	0.165	0.14	0 4141	0.1228	0.0124	0.1452	0.726
7	Channel	0.97	2.00	0.227	0.22	0.7825	0.413	0.0618	0.4748	1.000
8	Large angle	1.175	1.175	0.260	—	0.5245	0.0615	0.0615	0.1230	0.818
9	Small angle	1.00	1.00	0.185	—	0.3363	0.0275	0.0275	0.0550	0.656
10	Large tee	1.58	1.58	0.231	0.21	0.650	0.1459	0.0739	0.2189	0.911
11	Small tee	0.99	0.99	0.135	0.145	0.2573	0.0236	0.0108	0.0344	0.573
12	Large rectangular	0.87	1.96	—	—	1.70	0.5460	0.1075	0.6535	1.473
13	Small rectangular	0.51	1.62	—	—	0.827	0.1810	0.0180	0.1990	1.025
14	Square	0.96	0.96	—	—	0.920	0.0702	0.0702	0.1404	1.081
15	Hollow rectangular ..	0.872 in., 1.432 in × 0.0360 in. thick				0.151	0.0479	0.0223	0.0702	0.439
16	Hollow square	1.500 in., 1.500 in. × 0.0502 in.				0.296	0.1035	0.1035	0.2070	0.615
17	Large circular	1.01 in. in diameter				0.801	0.0510	0.0510	0.1020	1.010
18	Small circular . ..	0.876 in. in diameter				0.601	0.0288	0.0288	0.0576	0.876
19	Welded tube..	Outside diameter, 1.305 in. Inside diameter, 1.05 in.				0.473	0.0826	0.0826	0.1652	0.775
20	Solid-drawn tube	Outside diameter, 1.005 in. Inside diameter, 0.923 in.				0.124	0.0144	0 0144	0.0288	0.3980
21	Solid-drawn oval tube ..	0.862 in. × 1.74 in. × 0.045 in. thick.				0.1788	0.0515	0.0173	0.0688	0.4790

(2) The ordinary torsional formula—namely, $\theta = \frac{T L}{C J}$, where the symbols have the significance already ascribed to them—is based upon the fundamental supposition that transverse sections, originally plane, remain plane under torsion. That this supposition is justified in the case of a circular section is at once apparent from the following consideration. When a bar of circular section is subjected to a twisting moment, the consequent strain is such that two adjacent sections perpendicular to the axis of twist suffer a small relative rotation about the axis of twist—*i.e.*, the strain produced by the application of a torque—is one of pure shear. Where, however, the section is other than circular, complications arise. Transverse sections originally plane do not necessarily remain plane under torsion. Warping of the material takes place in planes perpendicular to the axis of twist. Where the torsional displacements are small, however, this warping can have little effect upon the torsional rigidity of a beam, and may in practice be neglected. The explanation of the great discrepancy that this investigation shows to exist between theory and practice in relation to the twisting of beams other than circular in section must then be sought for in another direction.

St. Venant (1797-1886) in his classical memoirs indicated that projecting points or corners in a beam section were a great source of inefficiency. His involved mathematical treatment of the subject cannot be given here, but a few specific examples will be of interest as bearing directly on the following experimental investigation. The following four examples are cited (see Fig. 1):—

1. Square section.
2. Square, with slightly concave sides and rounded corners.
3. Square, with slightly concave sides and acute corners.
4. Star-shaped section of four rounded points.

Assuming that the value of C J is a measure of the torsional strength of a beam section, St. Venant demonstrated that 1, 2, 3, and 4 were only 0.8434, 0.8186, 0.7783, and 0.5374 respectively as strong as would be anticipated from the formula $CJ = \frac{T L}{\theta}$.

In discussing the above results, St. Venant pointed out that the slight concavity of the sides of the square has more influence in diminishing the torsional strength of the beam (for the same moment of inertia) than the rounding of the corners has in increasing it. That where the square has curvilinear sides slightly more concave, and having acute angles, the torsional strength is reduced from 0.8434 to 0.7783 of its theoretical value, the concavity being in this case about $\frac{1}{10}$ of the length of the side. This shows in an astonishing manner the great effect that such a small concavity has upon the strength of a beam section. The greatest discrepancy between St. Venant's results and those obtained from the ordinary formula occurs in the case of section 4, which shows the extraordinary effect of projecting points in a beam section.

St. Venant sums up the whole comparison very tersely when he says that prisms having for their bases the rounded square, the pointed square, and the star shape, offer only 0.867, 0.828, and 0.674 respectively of the resistance to torsion of a prism having a circular base and of the same area of section, and therefore of an equal quantity of material, this notwithstanding the fact that the moments of inertia of their sections are respectively 1.059, 1.063, and 1.255 times that of a circular section of equal area.

Despite the fact that projecting points or corners have a considerable influence on the magnitude of the moment of inertia, they are remarkably inefficient in their effect on the torsional resistance of the section. Sections with projecting parts, as in an I-section beam, employed so usefully against flexure, ought to be eliminated from members of any structure where there is any tendency to twisting. Furthermore, St. Venant demonstrated that in symmetrical sections other than circular the greatest intensity of stress occurs at that point on the surface which is nearest to the axis of twist, and vanishes at a projecting point. The stress intensity becomes very great at the apex of a re-entrant angle, and where the apex of the re-entrant angle coincides with the centre of gravity of the section, it becomes infinite. This suggests that the maximum intensity of stress in an I section occurs at the junction of the flange and web; hence the necessity for a fillet of large radius. To illustrate further the inefficiency of isolated parts of a beam section, St. Venant chose an equation which gave him two isolated loops, as indicated in Fig. 2.

On the assumption that this represented a beam section subject to torque about the origin, St. Venant found that its torsional strength was only 0.0185 of its theoretical value as calculated from the base formula.

The above approximates very closely to the case of an I-section beam in which the metal is mostly concentrated in the flanges, the thickness of the web being small. Comparison between this and the experimental values on I beams recorded in Table II. is instructive. This analysis also suggests that an ordinary type of member used in structural work—viz., two flat bars kept apart by means of distance-pieces—must be excessively weak in torsion. St. Venant also calculated the torsional strength of a beam section analogous to that of an ordinary bulb-rail, but the writer has had no access to the results obtained in this case. The solution of all the above examples is only made possible because of the fact that the contours of the various sections are the graphical representations of definite mathematical equations, which allow of easy integration. The contours of ordinary commercial sections, however, do not have mathematical continuity, and for

Where a beam is subjected to both bending and twisting moments, the question becomes complicated, and in such a case it is necessary to take into account both the stresses and strains induced by bending and those induced by twisting. Such an example is afforded in the case of a bow-girder, which is circular in plan, and at each section of which both bending and twisting moments are in evidence. In such a case, indeed, the values of both bending and twisting moments at any section depend largely on the ratio of the moduli of twisting and of bending.*

Figures quoted in engineering text-books for the modulus of direct elasticity of materials have been amply confirmed, and it is generally recognised that such figures can be depended upon to give accurate results. The modulus of rigidity, however, varies widely even in specimens of the same metal, and, even if it were known accurately, its use in the calculation of torsional problems would lead—in all but the simplest cases—to errors of astonishing magnitude, as will be shown later.

Very little experimental work seems to have been done in this field of research, and to this fact the following investigation owes its existence. The primary object of the investigation was to obtain a relation between the longitudinal rigidity and the transverse rigidity of a beam, and to determine to what extent calculation based on a knowledge of the moments of inertia of the section and of the moduli of the material could be depended upon to give accurate results.

Notation.—In the following demonstration, the notation used is as follows:—

* "A Study of the Circular-Arc Bow-Girder," by Gibson and Ritchie. London: Constable and Co., Limited

this reason do not permit of rigid mathematical treatment. Recourse must therefore be made to experimental investigation, with the object of finding an empirical constant, by means of which the ordinary formulæ may lead to more accurate results.

Experimental Investigation.—In all, twenty-one beam sections were tested, the dimensions, &c., of which are entered in Table I. The to the nearest minute. The other end of the beam was firmly clamped to the head of the lathe, the gear being locked to prevent rotation.

On the addition of each increment of load, scale readings were taken at both pointers. In order to eliminate the effect of friction at the centres, the torque lever was elevated slightly, and allowed to descend slowly, depressed slightly, and allowed to hardened point was suspended from the middle point of the beam, and to this hanger was applied the load. Deflections were measured by means of a micrometer, fitted with a microscope which could be sighted on a silk fibre fixed to the beam. It was found possible to read deflections differing by 0.001 of an inch. Readings were taken for both loading and unloading, and the mean deflection

TABLE II.

No.	Type of Beam.	Axis of Fixture.	Deflection in Inches per 50 Lb. Load at Middle of 5-Ft. Span.	Observed Value of $E I \div 10^6$.	Observed Value of $E \div 10^6$.	Value of $E \div 10^6$ from Small Round Specimen.	Theoretical Value of $E I \div 10^6$.	Ratio: Theoretical E I / Observed E I	Angle or Twist in Degrees over 5-Ft. Span, per 50-In.-Lb. Torque.	Observed value of $C J \div 10^6$.	Value of $C \div 10^6$ from Small Round Specimen.	Theoretical Value of $C J \div 10^6$.	Ratio: Obser. C J / Theor. C J.	Angle of Twist in Degrees over 5-Ft. Span, from St. Venant's Formulæ, per 50-In.-Lb. Torque.	Diameter Circular Section of Equivalent Torsional Strength.	Observed Value of $\frac{E I}{C J}$.	Theoretical Value of $\frac{E I}{C J}$.	Ratio: $\frac{\text{Obser. Val. } \frac{E I}{C J}}{\text{Theor. Val. } \frac{E I}{C J}}$
1	I		—	—	—	—	2730.0	—	0.0137	12.52	—	1252.0	0.010	—	1.803	218.5	2.185	100.0
			—	—	—	—	390.5	—								31.15	0.311	100.0
2	Do.		—	—	—	—	110.8	—	0.1445	1.190	—	58.89	0.0202	—	1.0	93.10	1.886	49.4
			—	—	—	—	36.0	—								30.30	0.613	49.4
3	Do.		—	—	—	—	200.9	—	0.246	0.699	—	83.50	0.0084	—	0.877	287.0	2.410	119.0
			—	—	—	—	7.80	—								11.18	0.094	119.0
4	Do.		0.0038	59.0	30.70	30.00	57.80	0.979	0.645	0.2672	11.32	23.60	0.01129	—	0.701	220.8	2.445	90.7
			0.0485	4.65	26.40		5.310	1.141								17.41	0.225	77.5
5	Do.		0.0215	10.48	31.20	30.4	10.21	0.976	1.621	0.1063	11.30	4.110	0.0259	—	0.558	98.90	2.485	39.85
			0.2390	0.7810	27.80		0.8531	1.092								7.35	0.2075	35.47
6	Do.		0.0561	4.025	30.30	31.20	4.120	1.022	2.947	0.0585	11.68	1.091	0.0347	—	0.477	68.90	2.445	28.12
			0.5580	0.343	27.60		0.3860	1.127								5.86	0.229	25.55
7	Channel		0.0186	12.10	29.40	32.32	13.34	1.100	1.065	0.1618	11.61	5.510	0.0294	—	0.613	74.91	2.415	31.00
			0.1356	1.661	26.90		1.990	1.195								10.29	0.361	28.45
			0.1356	1.661	26.90		1.990	1.195								10.29	0.361	28.45
8	Large angle ..		0.1357	1.659	27.00	29.65	1.825	1.102	1.226	0.1405	10.95	1.342	0.1046	—	0.601	11.80	1.360	8.67
			0.1290	1.748	28.50		1.825	1.045								12.43	1.360	9.15
9	Small angle ..		0.3150	0.7130	26.00	28.72	0.7900	1.109	3.430	0.0501	11.00	0.605	0.0830	—	0.466	14.22	1.308	10.87
			0.3050	0.7390	26.90		0.7900	1.071								14.72	1.308	11.22
10	Large tee.. ..		0.0580	3.885	26.90	31.00	4.500	1.160	1.008	0.1706	11.50	2.508	0.0680	—	0.624	22.75	1.798	12.62
			0.0571	3.940	27.22		4.500	1.142								23.08	1.798	12.86
			0.1015	2.210	30.01		2.290	1.032								13.00	0.911	14.24
11	Small tee		0.3750	0.5990	25.32	30.00	0.7400	1.185	8.385	0.0205	11.41	0.3910	0.0524	—	0.365	29.20	1.818	16.10
			0.3810	0.5900	25.00		0.7100	1.201								28.89	1.811	15.82
			0.6084	0.3230	29.90		0.3240	1.002								15.78	0.827	19.10
12	Large rectangular		0.0145	15.50	28.41	28.01	15.260	0.985	0.0468	3.680	12.10	7.911	0.4645	0.0465	1.327	4.21	1.925	2.192
			0.0749	3.020	28.00		3.000	0.990								0.822	0.379	2.170
13	Small rectangular		0.0470	4.790	26.52	27.05	4.900	1.021	0.2800	0.6321	11.00	2.194	0.2900	0.2780	0.8711	7.56	2.24	3.38
			0.4750	0.4740	26.31		0.4900	1.033								0.750	0.224	3.36
14	Square		0.1181	1.905	27.10	29.8	2.095	1.098	0.1260	1.370	11.35	1.595	0.8591	0.1270	1.652	1.390	1.310	1.06
15	Hollow rectangular		0.1770	1.270	26.60	26.85 Assumed	1.230	1.008	0.3245	0.5310	11.00 Assumed	0.772	0.6880	—	0.8382	2.390	1.656	1.441
			0.3731	0.6010	27.10		0.595	0.989								1.133	0.770	1.472
16	Hollow square		0.0878	2.560	24.90	26.0	2.690	1.046	0.0870	1.975	11.00 Assumed	2.28	0.8670	—	1.163	1.301	1.180	1.102
17	Large circular		0.1632	1.380	27.12	—	1.380	1.000	0.1520	1.133	11.10	1.133	1.00	—	—	1.221	1.221	1.000
18	Small circular		0.2790	0.808	28.14	—	0.808	1.000	0.262	0.6570	11.42	0.6570	1.00	—	—	1.232	1.232	1.000
19	Welded tube		0.1010	2.230	26.05	—	2.230	1.000	0.0871	1.979	11.999	1.979	1.00	—	—	1.130	1.130	1.000
20	Solid-drawn		0.5400	0.4170	28.90	—	0.4170	1.000	0.500	0.3465	11.99	0.3465	1.00	—	—	1.202	1.202	1.000
21	Solid-drawn oval tube		0.1696	1.3250	25.7	25.31 Assumed	1.302	0.985	0.3480	0.4951	11.00 Assumed	0.755	0.6560	0.4640	0.8240	2.66	1.73	1.540
		(Section)	0.5300	0.4255	24.92		0.4310	1.010								0.858	0.571	1.501

solid rectangular sections, the solid circular sections, and the welded tube were of wrought iron; the others were of steel. The method of carrying out the torsion tests was briefly as follows:—The beam under test was mounted between the centres of a 6-ft. lathe, centre-pops being made on the ends of the beam, at the centre of gravity of the section, to receive the lathe centres. To one end of the beam was clamped a lever, from which was suspended a hanger fitted with a knife-edge and carrying the load. Two pointers, each 3 ft. long, could be clamped to the beam at any desired position. These pointers moved over scales, firmly clamped to the bed-plate, and graduated in degrees and minutes. Readings could be accurately taken rise slowly, the angle of mean position being noted. Observations were made for both loading and unloading, and the mean angle of twist per unit of load so obtained. The value of the product of C and J was then found from the formula—

$$C J = \frac{T L}{\theta},$$

where the symbols have the significance already ascribed to them. In each case the experiment was repeated over a span of about half the original span. In no case did the two values of C J, so obtained, differ by more than 3 per cent. The values of the product of E and I were found by supporting the beam on two massive knife-edges firmly bolted to the bed-plate. A hanger fitted with a per unit-load calculated. The value of E I was then found from the relationship—

$$E I = \frac{w l^3}{48 \delta}.$$

In order to obtain the values of the two moduli E and C, specimens were cut from the thickest part of each section and carefully turned down to a diameter of about 0.18 in. and cut to a length of about 9 in. The values of C were then found by means of a small torsion-meter, and the values of E determined by supporting the specimens on knife-edges and applying a load at the middle of the span. The values of the constants so found have been tabulated in Table II.

(To be continued.)

GRINDING-MACHINES.—No. XVIII.

By JOSEPH HORNER.

THE subject of cam-grinding is of much present interest, because cams are used to such an enormous extent in internal-combustion engines. The war has vastly quickened the demand, notably for aeroplane shafts, on which it is common to have twenty-four cams formed integrally with the shaft. The extremely high rate of rotation, and the importance of producing the cams within very fine limits of inaccuracy, invests the methods of grinding with a special interest.

Two methods may be employed for grinding a cam to its finished shape. The first is done by oscillating or swinging either the work or the wheel; the second by a sliding movement of either the work or the wheel. The first is generally adopted for the smaller sizes of cams, and affords the finer degree of accuracy owing to the more sensitive control; the second is used for the larger sizes of cams. Both methods will be illustrated in this article. The grinding of the cams which operate the valves of internal-combustion engines is an interesting example of form or copy-grinding. In the early days the cams were keyed on their shafts and filed singly, each for its own valve. Invariably now cams are made integral with their shafts, comprising one solid forging, with the result that no risk of movement from their original position is incurred, and a good deal of fitting is moreover abolished. The photograph reproduced in Fig. 259 shows a group of cam-shafts ground on Churchill machines at the works of the Moss Gear Company, Limited, of Birmingham. The photograph includes shafts ranging from the new 12-cylinder 150-horse-power super-aeroplane engines down to the small X-ray trench-lighting sets. All the shafts are for war purposes.

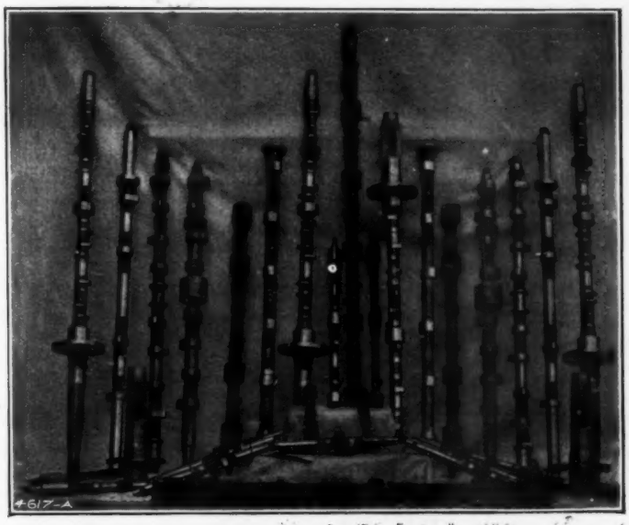


FIG. 259. GROUP OF CAM-SHAFTS.

The drawings, Figs. 260 to 263, reproduced on Plate III., illustrate one of the Churchill cam-grinding attachments for dealing with cams integral with the shaft. This attachment is mounted either on one of the plain or one of the universal machines of this firm. The photograph, Fig. 264, also given on Plate III., represents a similar attachment, but one which is capable of grinding single or double combined cams up to 4 in. maximum radius. This view will be helpful towards the understanding of the drawings.

The attachment consists of an oscillating table which carries a driving-head integral with it, and a loose head, between the centres of which the cam-shaft is carried. The oscillating table with its heads is supported in trunnion-brackets which are fitted and clamped to the regular table of the machine. It swings the work towards and from the grinding-wheel as the cam-shaft revolves, the motion being controlled by a master-cam.

The work-spindle A is rotated from the belt-pulley B at the left hand. It drives through speed-reduction gears, so arranged that the oscillations of the work-head will not interfere with the meshing of the gears. The pulley-shaft is carried in the trunnion-bracket C, which is fixed to the vees of the bed by diagonal clamping-bolts, shown in Fig. 262. The pulley-shaft drives round to the oscillating work-head D through the gears *a*, of forty-nine teeth, and *b*, of fifty-three teeth. The shaft E, on which the latter is keyed, carries at its farther end the pinion *c*, of eighteen teeth, which drives one, *d*, of nineteen teeth, and this to the gear *e*, of forty-seven teeth, on the work-spindle A carried by the oscillating head D. The nineteen-toothed pinion *d* is an idler, running loosely on a shaft fixed in the oscillating head (compare with the plan view, Fig. 261). The gear *a* and the driving-pulley B run on a sleeve which is common to both (see Fig. 260).

The oscillations of the work-head are derived from the master-cam F. There is an eccentric-shaped roller-housing *f*, Fig. 261, carried in an arm contained by the front portion of the headstock or trunnion-bracket C, the latter being fitted with a bracket to receive and confine the roller-housing. The short shaft which passes through the roller-housing carries a roller *g*, lying in a slot in the housing. The roller bears against the edge of the master-cam F, so that the work-spindle is compelled to respond to the outline of the cam mounted upon it, under the coercion of the roller. The weight of the overhanging portion of the trunnion-head about the roller maintains the cam and roller in contact. The eccentric shape is imparted to *f* in order to permit the roller-bearings to come snugly up to to the cam. Two cam-discs F are shown (not yet ground to shape), one being for working the inlet, and the other for actuating the exhaust-valve. The roller is brought up against either cam by sliding the housing *f* along key-guides. The bolt *h* clamps it in either position when in contact with the internal shoulders, Fig. 261. The entire mechanism of the work-head and tailstock, with the bed on which both are mounted, is oscillated to and from the grinding-wheel in response to the contour of the master-cam.

The drawings show the method of driving the shaft which is being operated upon, this being done by a fork G attached to the division-plate H. The locking-pin *j* is pivoted, and is thrown into and out of its divisions, and held in the in and out positions by a spring plunger *k* having a conical end-thrust. The tail-stock J, Fig. 263, is of the spring type, with provision for adjusting the power of the spring.

It will be noticed in these illustrations of the oscillating attachment that although a cam-shaft may have any number of cams, only two master-cams are used, one each for the inlet and the exhaust-cams respectively. It is common practice now to add a third master-cam for the purpose of grinding the air-pump eccentric. This does not in any way affect the principle involved. The two, or three, master-cams, as the case may be, are always formed from one piece of tool-steel, generated, hardened, and ground to the correct shape and with the exact angular relationship between the inlet and exhaust, so that no variation can possibly occur in actual use. To take care of the varying number of engine cylinders and their respective cams the dividing plate forms part of the attachment and is indexed round as occasion requires.

In the actual practice of grinding cams integral with their shafts it is customary to rough-grind the cams to shape from the circular blank as left from the turning without any previous milling. This method may at first sight appear to be slow and uneconomical, but it is, in fact, the quickest and by far the most efficient method of removing the surplus metal. This is entirely due to the high rotative speed imparted to the cam-shaft during grinding, with resulting slight stress on the shaft, while in milling the cam-shaft has to be rotated slowly, with correspondingly increased torsional stress. After the cams have been roughly ground to shape, being left sufficiently large to allow for distortion consequent on hardening, they are hardened, the shaft straightened, and the bearings finish-ground. Afterwards the shaft is placed in the grinding-machine, and the cams are finish-ground. In the roughing and finishing operations the cams nearest the driven end of the cam-shaft should be ground first, and those nearest the tailstock of the attachment last, so that any strains which may have been released in the shaft by the removal of the surplus metal are taken care of.

To produce by hand methods a master-cam of large diameter from a small model is practically impossible, and it would entail much of cut-and-try methods. The actual working cams were so made by hand in the early days of gas and oil-engines. Messrs. Churchill adopt the following method of producing master-cams for the oscillating type of machine. After the correct particulars of a cam have been obtained, a model is made four times larger than the actual cam to be reproduced. This is placed on a reducing attachment, and the master-cam is there ground to its correct size and shape in the relation of 1 to 4 of the larger model. In this way any slight errors which may exist in the large model are proportionately minimised, and the action, once the large model has been produced, is a purely mechanical one. The degree of approach to accuracy of the master-cam is thus increased in proportion as it minimises any inaccuracy which may exist in the large model. This method of generating master-cams from a model is so accurate that the error between any inlet-cam and its respective exhaust-cam can be guaranteed within ¼ deg., or 0.0005 in. of correct shape measured in any direction.

The next illustrations we will take are those of a Churchill cam-grinding machine of the reciprocating type, the 16-in. size, this being shown by Figs. 265 to 271, on Plate III. A good general idea of its design can be gathered from the photograph reproduced in Fig. 267, while the details are clearly illustrated by the drawings, Figs. 268 to 271. But it will simplify matters if attention is first directed to the diagrams on the next page, of which Fig. 272 represents the operation of grinding cams, and Fig. 273 that of grinding the master-cams. Reference may also be made to the skeleton drawing of the machine, Figs. 273 and 274, on Plate III., used for erection purposes. We can afterwards follow these out on the drawings of the assembled machine in Figs. 268 to 271.

Fig. 272 shows the equipment used for grinding an engine-cam from a master-cam. Fig. 273 illustrates the grinding of a master-cam from a model. It will be observed that each process is a reversal of the other. In Fig. 272 the master-cam is under the control of a roller. In Fig. 273 the place of the roller is taken by a grinding-wheel of the same size as the roller, while the place of the grinding-wheel in Fig. 272 is taken in Fig. 273 by a roller of the same size as the wheel, which roller is maintained in contact with the model. The master-cam in Fig. 272 is kept in contact with the roller by a weight (Fig. 267) pulling in the direction of the arrow. The roller in Fig. 273 is maintained in contact with the model by the same weight pulling in the opposite direction.

The method of mounting the cam to be ground, and its respective master-cam, is seen in the sectional view, Fig. 274. The arbor which carries both cams is shown in detail. It is itself carried on a

conical arbor, mounted in the spindle-nose of the work-head and held by a draw-bolt. It is advisable to provide a work-arbor for every different shape of cam intended to be ground on the machine. Also the master-cam should be permanently mounted on each respective work-arbor and marked with its respective symbol or identification mark. This system is adopted in order to eliminate as far as possible errors which arise from mounting cams incorrectly, and it ensures that the engine-cams will be ground in correct relation to the keyway. The keyway in the work-arbor must, of course, be in its correct relation to the master-cam. Small cams in which the bore is too small to be carried on a cast-iron intermediate work-arbor have to be carried directly on an arbor mounted in the spindle-nose.

The headstock which carries the cam-spindle has a straight-line motion only, and is in the same plane as the wheel-head spindle. Once a correct master-cam has been generated, no variation in the shape of the ground cam, as given by the master-cam, can occur except by the development of variations in the diameter of the grinding-wheel due to wear.

Fig. 272. GRINDING ENGINE CAM.

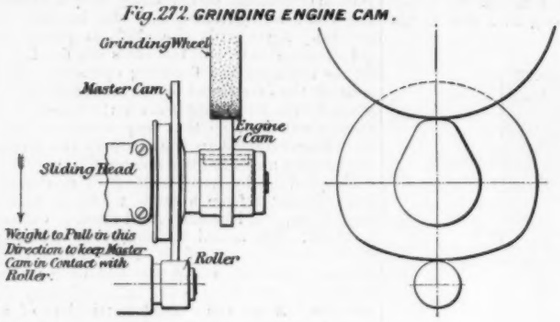
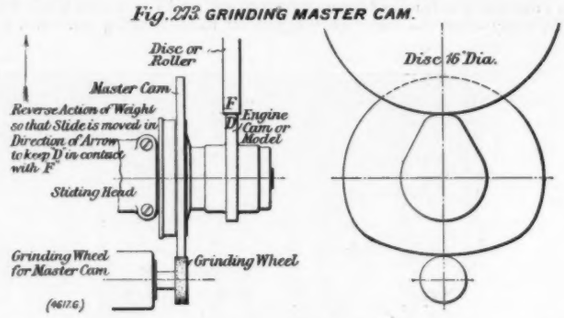


Fig. 273. GRINDING MASTER CAM.


Disc or Roller
Master Cam
Reverse Action of Weight so that Slide is moved in Direction of Arrow to keep D in contact with F
F
D
Engine Cam or Model
Sliding Head
Grinding Wheel for Master Cam
Grinding Wheel
Disc 16 Dia.
(4617.G)

For the machine now being dealt with, the diameter of a new wheel is 16 in., and experience has shown that it can be used down to 14-in. diameter before the error in the cam becomes greater than permissible. But for the roughing-out, wheels much smaller can be used, because the effect of a small wheel is to leave an excess of metal on the rise-and-fall portions of the cam; an error which is easily remedied when finishing, by using the correct wheel. The diameter of the grinding-wheel used is dependent on the diameter of the roller employed when developing and grinding a master-cam (Figs. 272 and 273). If cams are required with hollow sides, it naturally follows that the side of the largest roll that can be used is fixed by the radius of the hollow sides of the cam. The standard diameter of the master-cam intended to be used on the machine is 16 in., taken on the base or circular portion, and the diameter of the roller working against this cam is 3 in.

The essential action of the cam-grinding machine may now be gathered from the erection drawings (Figs. 265 and 266), in which the same references occur as on the detailed assembly drawings (Figs. 268 to 271). Assuming that the master-cam has been ground and that the machine is engaged on grinding cams, the chain of the weight W must be so placed on the disc Q that its effect is to draw the cam-spindle headstock directly on to the roller U in the bracket (compare with Fig. 270). The cam to be ground is carried on the work-arbor. The operation of grinding then proceeds in the ordinary way, by means of the automatic feed imparted to the lower slide of the work-head A (compare with Fig. 268). The grinding-wheel headstock is caused to oscillate across the face of the cam being ground by means of the crank T driven through the worm-gear and vertical shaft shown by the fast pulley D, which is started and stopped by the handle R.

These operations being clear, the operation of grinding master-cams is the exact reverse. The grinding-wheel on the main wheel-spindle is removed, and a roller (supplied with the machine and of the same diameter as the grinding-wheel, as explained in connection with Fig. 273) is mounted on the spindle. The action of the weight W in Fig. 265 is then reversed on the chain-pulley Q, in order to cause the cam-spindle headstock to be forced against the grinding-wheel spindle, so that the roller mounted on the wheel-spindle comes into contact with the model cam mounted on the work-arbor in the cam-spindle. The roller U in the bracket is then removed, and a small grinding-wheel spindle is inserted and driven from the pulley X on the counter-shaft. When grinding master-cams in the way described, the feed to the grinding-wheel is obtained through the slides of A, it being imparted by the automatic feed of the machine in exactly the same way and in the same direction as when grinding engine-cams.

The assembly drawings may now be taken of the 16-in. machine—that is, one which is capable of grinding cams up to 8 in. radius. It is shown in front elevation, Fig. 268, and end view, Fig. 270, taken at the left-hand end. Its two main elements are the work-head A, driven from a four-stepped belt-cone B (compare with Fig. 266) with a 1½-in. belt from the counter-shaft, and the grinding-wheel head C, which is driven by a 3-in. belt from the counter-shaft to a two-stepped pulley on the head. The work-head is fed micrometrically in a horizontal line towards the wheel. The latter is traversed past the cam, which it grinds; primarily from a 1½-in. belt from the counter-shaft, Fig. 266, to fast and loose pulleys D, thence through gears and the connecting-rod T described later. We

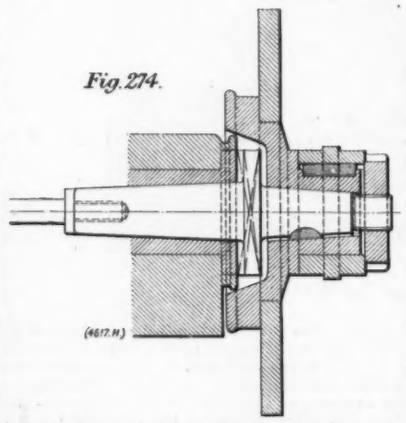


Fig. 274.

will now trace out the details, commencing with the work-head.

The four-stepped belt-cone B, deriving four speeds from the counter-shaft, is clutched to the pulley E, which drives to the work-head A through the medium of a sleeve with its fork F, and its series of levers terminating with G, the latter being located at the front, close to the feed-disc. As the work-head A occupies different positions along its slide, the driving-belt coming from the pulley E is tightened by a binder-pulley H on its way to the driving-pulley J on the head. The binder-pulley is carried on an arm that swings around the centre of the driving-pulley J, and the arm is set and clamped in a quadrant K. From the pulley J the drive to the work-arbor takes place at a greatly reduced speed through a train of gears, shown in plan in Fig. 271, which gears are encased in a hood. The position of the last gear L, of 100 teeth, is seen in the front and end elevations. It occupies (Fig. 268) the rear end of the spindle, the other end of which carries the cam to be ground and the master-cam M, as shown in section in Fig. 274.

The work-head A slides on a flat and a V'd edge on the base, with a gib, as seen in Fig. 268. It is fed micrometrically by the firm's standard feed equipment, which is slightly modified in order to suit the particular movement. At each revolution of the work-spindle N, a pin *a*, Fig. 270, strikes a spring plunger *b* which presses an abutment-piece on the stop *c*, which is adjustable along the bar O, on which it is clamped. The effect is to move the quadrant *d* through an arc, and from it to the lever *e*, to the other end of which a pawl is hinged. This engages with the teeth of a ratchet-wheel that forms a portion of the feed-disc P and hand-wheel at the front of the machine, Fig. 270. The amount of the feed is set at sight by graduations on the quadrant *d*, to which the lever *e* is set and clamped. Graduations are made on the hand-wheel to thousandths of an inch, and the ratchet has four teeth to each graduation on the hand-wheel. Each tooth on the ratchet therefore feeds to one four-thousandth of an inch (0.00025 in.). The small index-wheel, seen on the face of the hand-wheel in Fig. 267, carries an indicator, which, when moved a given number of spaces forwards or backwards, traverses a trip-cam round a corresponding number of teeth on the ratchet-wheel, and disengages the feed at a predetermined stage of reduction. The feeds are transmitted through spur-gears *f* and *g*, of 22 and 56 teeth, to a worm-shaft *h*, the worm of which drives a worm-wheel *k* and spur-pinion *l* that engages with a rack *m* beneath the work-head.

The disc Q, Fig. 268 (compare with Figs. 265 and 266), is, as already stated, an attachment for the chain which carries the weight W that pulls the entire head over and maintains contact with the roller.

The grinding-wheel head and the method by which it is driven are seen in Fig. 268. The fast and loose pulleys D are driven by a 1½-in. belt from the counter-shaft, Fig. 266. The belt-shifter R is moved by a hand-lever. The pulley-shaft carries a worm *n* which drives a wheel *o* (see the plan detail, Fig. 269). The wheel-shaft carries a disc S at its upper end with a screw *p* and nut *q*, the latter with a stud which drives a connecting-rod T, the other end of which, being attached to the lower face of the wheel-slide, reciprocates it, traversing it past the work that is being ground. The screw *p* provides the means for the adjustment of the length of stroke. The longitudinal position of the wheel relatively to the work is adjustable with a pinion *r* and rack *s*, the hand-wheel operating which is seen in the photograph, Fig. 267, and at V in Fig. 266.

HYDERABAD.—A fine new station in the Indian Saracenic style, designed by Mr. Vincent J. Esch, is being erected at Hyderabad for the broad-gauge Secunderabad and Gadaj Railway. The work is now well in hand, under the direction of Mr. A. G. Pears, engineer-in-chief of the Nizam's Guaranteed State Railway. The site of the new station is several miles from the present building, and it is nearer the river and on higher ground. The new station is 264 ft. long by 49 ft. wide, and the main entrance is in the centre. Two sets of waiting-rooms have been provided for passengers who have to spend several hours at the station. Designs have been prepared for a similar station at Secunderabad.

INDIAN IRRIGATION.—The Upper Jhelum Canal has been officially inaugurated at Mangla by the Viceroy of India. The first nineteen miles of the canal are situated in the Kashmir territory, and his Highness the Maharaja of Kashmir gave all the land required for the works within his territories free of cost. The canal will be beneficial to the State, as some 6000 acres will be annually irrigated from distribution channels which the Kashmir Durbar is now constructing. The canal was designed by Sir J. Benton, and Messrs. Mullaly, Bennett and Purves were also concerned as engineers. The inauguration of the canal was effected by the Viceroy raising one of the sluices. The Viceroy was presented with a souvenir of the occasion in the form of a bowl with local canals embossed in relief upon it—in front the Upper Jhelum, and on the back the Lower Bari and the Upper Chenab.

ELECTRIFICATION OF THE MANCHESTER TO BURY SECTION; L. AND Y. RAILWAY.

(For Description, see Page 55.)

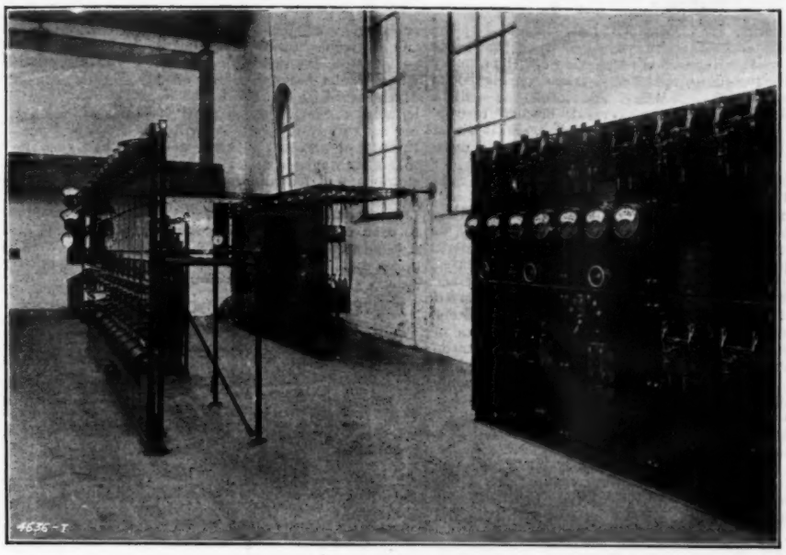


FIG. 23. MAIN CONTROL SWITCHBOARD.

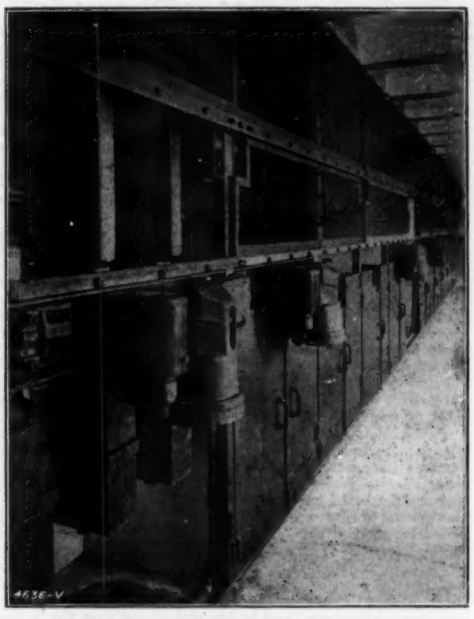
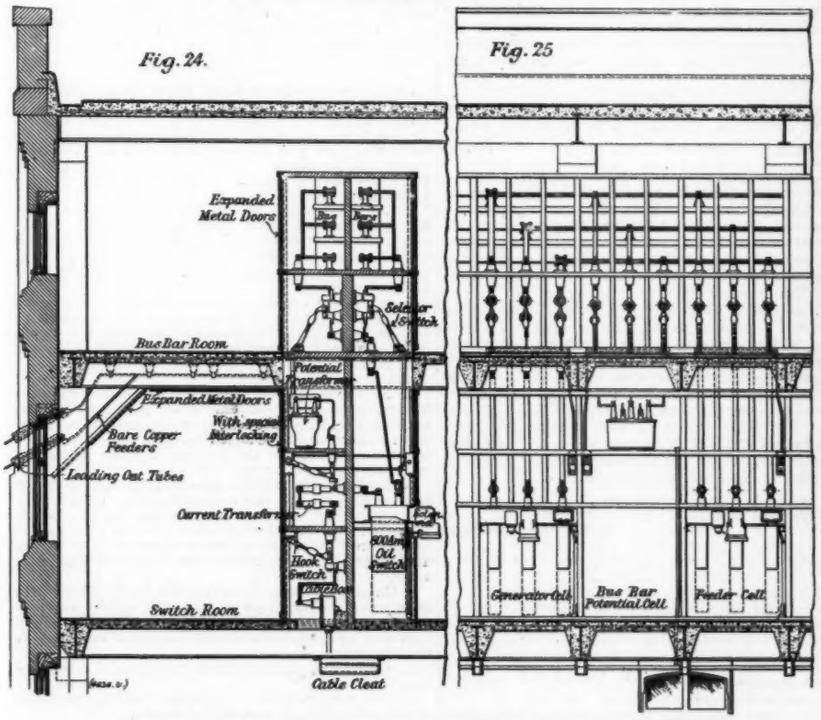


FIG. 26. SECOND FLOOR OF SWITCH-HOUSE.



FIGS. 24 AND 25. CROSS-SECTION AND PART ELEVATION OF SWITCH-HOUSE.

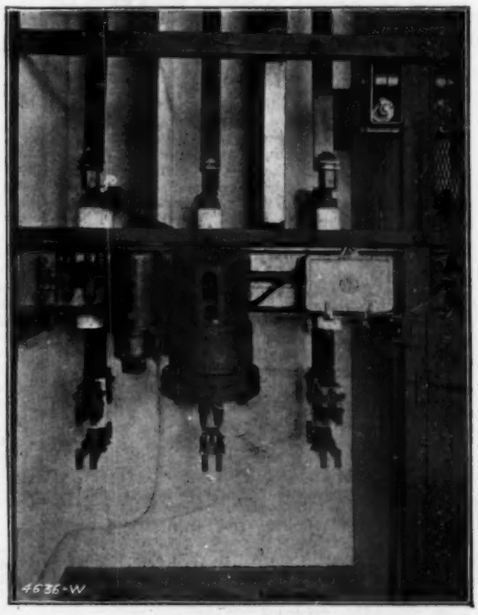


FIG. 27. OIL-SWITCHES.

SLEEPERS FOR INDIAN RAILWAYS.—Nearly 2000 sleepers are required for every mile of broad-gauge Indian railway, and as the life of a sleeper is estimated at ten to twelve years, a great quantity of timber is required annually by the Indian lines. One of the best timbers now used for sleepers is the Himalayan cypress, or deodar, which grows at elevations of from 6000 ft. to 9000 ft., along the valleys of the rivers in the north-west Himalayas. The deodar is of comparatively slow growth, but it is long-lived. It takes at least 120 years to reach maturity, and in many forests trees 800 or 900 years old are to be found. It sometimes attains a height of 200 ft., with a girth of over 30 ft., but such trees are rare. The deodar forests of the Punjaub and the United Provinces are the most important with which the Indian Forest Department deals. Until recently the Forest Department worked out itself all the timber derived from its forests; but now in most localities a forest officer simply marks the trees to be felled, and these are sold to a contractor. It requires careful and skilful management successfully to fell the deodar, as it grows in precipitous countries, and if not felled properly it dashes down the hillside, and by the time it reaches the nullah below there is little left but a mass of matchwood. The tree having been felled, it is logged into 10-ft. lengths, then squared with an axe, and finally sawn into sleepers. Sawing is a slow process, as it is all done by hand. The deodar forests are found along the valleys of most of the rivers of Upper India, but the majority of them are high up on the slopes of the small side nullahs, and at a considerable distance from the main stream, by which they are ultimately conveyed to their destination. The first stage in the development of sleepers is to carry them down from the forests to the banks of the nearest stream, which is sometimes as much as 10 miles away. This is the hardest part of the work. Subsequently the sleepers are worked down the side streams to the main river.

THE NEW LIGHTING REGULATIONS FOR MOTORISTS.—The Automobile Association and Motor Union has arranged for the manufacture of a special type of lamp-disc for use by motorists when entering the areas where the new Order, which came into operation on the 10th inst., renders the use of such discs compulsory. Members who require these discs should immediately communicate (stating the diameter of the front glass) with the Secretary, Fanum House, Whitcomb-street, London, W.C.

SWISS RAILWAYS.—During the past year three important new lines have been completed—viz., first, a great tunnel with approaches under the Mont d'Or between Frasne and Vallorbe; secondly, the Moutier and Granges line, which appreciably abridges the running distance between Paris and Berne; and, thirdly, the Hauenstein tunnel on a line from Basle to Lucerne. The first line is 15 miles, the second 8½ miles, and the third 5 miles in length. Each of the three lines has involved the construction of an important tunnel, the first extending over 3¾ miles, the second 5½ miles, and the third 5 miles.

INDUSTRIAL NOTES.

THE outstanding feature of the labour market in the year 1915, says the Director of the Department of Labour Statistics, was the shortage of workpeople, which became more and more pronounced as the year advanced, and was very acute at its close, owing to the active recruiting campaign that took place in the autumn and early winter. A few industries, including some of importance, such as the building trades and some branches of the clothing trades, were relatively quiet, though even in these the staffs of workpeople were so much depleted that there was very little unemployment, and, as a rule, only a small amount of short time. In the large majority of trades, however, the great difficulty was scarcity of labour, which was met to some extent by the working of overtime.

The shortage would have been even more severely felt but for the transfer of workpeople from one industry to another, the "dilution" of skilled by semi-skilled and unskilled labour, and by the greater employment of women and girls, partly on classes of work formerly shared between males and females, and partly on work hitherto performed exclusively by men and boys. Speaking generally, it may be said that the growing shortage of male labour can only be met by a very much larger influx of women into industry than has yet taken place.

From the commencement of the war until the end of 1914 there had been comparatively little change in rates of wages generally. At the beginning of 1915, however, the increasing shortage of labour, together with a rise in the cost of food and clothing, led to a demand for higher wages, and in February, 1915, a sharp upward movement began, largely in the form of war bonuses or of special advances in rates limited to the period of the war. In the main the industries primarily affected were those directly concerned with the manufacture of munitions or with the transport of troops and supplies—*e.g.*, engineering and shipbuilding, railway service, dock labour, and carting; but the movement subsequently spread to nearly all the important industries, and by the end of the year the aggregate effect on weekly wages of all the war bonuses and increases in rates of wages which had been granted far exceeded that recorded by the department in any previous year. Concurrently the general level of wages was raised by transfers of labour to munition and other factories specially concerned with war requirements.

At the beginning of 1915 retail prices of food were about 18 per cent. above the normal prices of July, 1914, the month before the war. On January 1, 1916, the corresponding increase was 45 per cent. The months during which the greatest increases occurred were January, May and September. The January advance was largely due to the increases in the prices of bread and flour, that of May to the advance in meat prices, and that of September to the increases in the amount of duty on tea and sugar. In addition to the rise in food prices, there was also a substantial increase in the retail prices of boots and clothing, particularly in the second half of 1915. On the other hand, the increase in the prices of fuel, light, and other items of domestic expenditure was not so marked, and, except in a few places, mostly in munition areas, rents remained practically unchanged.

As regards wholesale prices, it is interesting to note that the index number for 1915 was below that of 1872-4, the years immediately following the Franco-Prussian War.

The number of disputes beginning in the past year (674) was less than was the case in any of the four previous years, and the totals of the number of workpeople involved (445,936) and aggregate duration (2,969,700 working days) were less than those for any of the five preceding years. In each case the figure for 1915 was below the average for the nine preceding years, the aggregate duration of the disputes in progress during the year being less than one-third of this average.

Measured by aggregate duration, all the groups of trades, with the exception of the transport group, were less affected by disputes than in the previous year, this being most marked in the building, engineering, and other metal groups. The high figures for the coal-mining industry—77 disputes, involving 296,064 workpeople, as against 58 disputes, involving 271,242 workpeople, in 1914—are entirely due to the strikes in the South Wales coal-field, which began in July and August, following on the breakdown of negotiations for a new wages agreement. In the first of these some 200,000 miners were involved, and in the second 32,000; and the aggregate duration for the two disputes amounted to nearly 1,400,000 days, about half the respective totals for the year for all trades. About one-half (110,000 working days) of the total aggregate duration of disputes in the engineering trades is accounted for by the strike of nearly 9000 engineers on the Clyde, which occurred in February and March, and arose on a demand for an advance in wages of 2d. per hour. Nearly one-third (110,000 working days) of the aggregate duration in the textile group is due to the strike of 1200 weavers near Burnley for the payment of standard list prices, which began on August 25, and is still unsettled.

At the end of the year only thirteen disputes, involving 3300 workpeople, were in progress.

The report for December last, issued by the United Pattern-Makers' Association, states that trade afforded some indication of slackening off, the number of members signing the Association's vacant-books showing a slight increase. The total was still a negligible quantity, but several branch returns showed trade as being dull or declining, and it would seem as if the falling-off was due to something more than a temporary and unimportant shuffling of employment between one shop and another. Trade was still exceedingly good on the North-East Coast, and almost as good throughout the Clyde district, although for the moment more members were out of employment than was usually the case in that centre. The majority of the unemployed members were located in the inland districts, Manchester being about the worst off in this respect. Fifty-two branches reported having 413 members employed at occupations other than pattern-making, owing to the requirements of the Government. There appeared to be no reason why that number should not be raised to four figures. The Minister of Munitions had declared that he must have 60,000 skilled men to man his Government factories and supply the deficiency in controlled establishments. The Association had already proved that its members could supply a proportion of that shortage by releasing mechanics who were at present engaged as markers-off, viewers, gaugers, and the like, whilst there were plenty of members who were competent millwrights, and could even do fitting and turning, whilst the shortage in the pattern-making trade could easily be met by placing the remainder on overtime. This, however, was a local question which could only be met locally; the suggestion was thrown out, not only with a view to the absorption of the unemployed members, but as a part remedy for the present shortage of skilled men, which seemed likely to cause the Government considerable difficulty in the near future.

The report for January of the Steam-Engine Makers' Society shows the membership to be 18,500, whilst the capital is 155,000*l.*, and the number of unemployed three.

"On looking through one of the Stock Exchange reference-books," says Mr. F. G. Hatch in a paper read before the Junior Institution of Engineers, on the 10th inst., "details of a number of companies of general and electrical engineers were found, from which it was possible to get some indication as to their earnings. The number of firms mentioned was thirty-eight, excluding steel and iron works, shipbuilding yards, and armament works. It included well-known firms, making, among other things:—Water-tube boilers; electrical plant of every description; agricultural machinery; gas and oil-engines; electric tramway and railway plant; mining machinery; printing machinery; textile machinery, &c.; locomotives. The total capital of the thirty-eight firms amounted to 21,000,000*l.* in round figures. Over the period of nine years the following average dividends were paid by these thirty-eight firms:—

1 averaged		19.6 per cent.					
2 averaged	over	15	,,				
1 ,,	,,	10	,,	and	under	15	per cent.
2 ,,	,,	9	,,	,,	,,	10	,,
3 ,,	,,	8	,,	,,	,,	9	,,
2 ,,	,,	7	,,	,,	,,	8	,,
3 ,,	,,	6	,,	,,	,,	7	,,
10 ,,	,,	5	,,	,,	,,	6	,,
4 ,,	,,	4	,,	,,	,,	5	,,
3 ,,	,,	3	,,	,,	,,	4	,,
3 ,,	,,	2	,,	,,	,,	3	,,
1 ,,	,,	1	,,	,,	,,	2	,,
1 averaged	under	1	,,				
2 paid no dividends.							

"The period taken was the year 1913 and the eight years preceding. From the above figures it may be taken that between 5 and 6 per cent. represents the average return upon capital invested in general engineering.

"Can these results be called satisfactory? If there were security of capital in the same way that there is in Consols and other trustee stock—yes. Without this security—and a glance at the lower portion of the table will show that there is not this security—then the answer must be in the negative."

According to recent official statistics there were in Denmark last year 156,000 organised skilled hands—an increase of about 66,000 in the course of ten years. Of the above total, 121,000 belonged to the central organisation—the Co-Operating Trade Unions.

"We have heard a great deal," says a writer in the *Iron Trade Review*, Cleveland, Ohio, "about the possibilities of cheap production in Europe, a production spurred on by the goad of debt and the ambition to recover lost markets and prestige. Against this must be set off the probability that the ranks of expert machine-tool operators will be seriously depleted, not only by death and wounds in battle, for a great proportion of these workers to-day are behind the lines supplying munitions, but by the inevitable redistribution of labour into depopulated fields, such as that of agriculture, for instance. It is the peasant soldier whose ranks have been the most seriously thinned. Machinists will be tempted away from their vocation by more attractive opportunities in lines which, needing workers more seriously, will offer better prospects. In spite of national poverty, there will be a tendency to higher wages in specialised lines. Here American supremacy in machine-tool development will have its innings. Against European industry, which, generally speaking, requires an individual skilled operator to each machine, we may summon up our automatic methods, in which one man handles from two to a dozen tools."

EXCESS PROFITS DUTY UNDER THE FINANCE ACT (No. 2), 1915.

THE Machinery Users' Association (Incorporated) have issued the following explanations of the incidence of Excess Profits Duty, dealing particularly with those points which appear for the moment to give difficulty to persons interested in this duty:—

1. The duty is 50 per cent. of the amount by which the profits during the "accounting period" exceeded by more than 200*l.* the "standard of pre-war profit."

2. The "accounting period" is any account year which ended after August 4, 1914, and before July 1, 1915.

N.B.—Accounts ending on and after July 1, 1915, will presumably be dealt with in future Budgets. The question of "account year" has given difficulty to many persons, but it should be remembered in dealing with this duty that it is retrospective, and only deals with liabilities which have occurred up to July 1, 1915. Those whose account years end between July 1 and August 4 are not interested in the present return. The next Budget dealing with this tax will presumably be for the twelve months ending June 30, 1916.

3. The "pre-war standard" is:—

(*a*) The average profit of any two of the last three pre-war years.

(*b*) If any special circumstances have adversely affected the last three pre-war trade years, four of the last six pre-war trade years may be substituted. Adverse affectation means that the average profits during the three pre-war years has been at least 25 per cent. less than the preceding three years.

(*c*) If the average profits are less than the "percentage standard," the following percentage of the capital employed may be substituted:—6 per cent. in the case of a trade or business carried on or owned by a company or other body corporate; 7 per cent. in any other trade or business.

4. Increase of capital which has been made during the "war profit" year is to be accounted for by deducting from the war profits the statutory percentage per annum on the amount by which the capital has been increased. This principle also applies to capital not fully used during the three pre-war years.

5. In arriving at the excess profit, the same rules are followed as those for ascertaining the profits for income tax, Schedule D; but the following adjustments are necessary:—There should be added back the following items: interest on loans for the purpose of trade, rents and royalties, and such like expenses.

N.B.—This adjustment is necessary, as what is desired is a comparison and the ascertainment of what are the "excess profits," and it is possible that the interest on loans and overdrafts for the purpose of earning the war profits considerably exceed the charges incurred during normal years, and therefore due allowance should be made.

6. On application by the taxpayers, the Commissioners have power to take into account and modify the provisions which apply to the computation of profits, where the following special circumstances arise and warrant such modification:—

(*a*) Owing to a change in the constitution of a partnership.

(*b*) The postponement or suspension, as a consequence of the present war, of renewals or repairs.

(*c*) Exceptional depression or obsolescence of assets employed in the trade or business due to the present war.

(*d*) The necessity in connection with the war of providing plant which will not be required for the purposes of the trade after the war.

(*e*) Any other special circumstances to meet the particular case.

7. An appointed Board of Referees has power to increase the "statutory percentages." This refers to cases where:—

(*a*) The amount of capital employed is small owing to the peculiar circumstances of the trade.

(*b*) Where capital is employed for the manufacture of war material, or for munition work, which could not be expected to be remunerative except in time of war.

8. It is noted that the deductions for wear and tear and renewals follow the rules provided under the Income-Tax Act.

It would appear that the intention is not to interfere with the usual rules governing allowance for "wear and tear," but that neglected repairs and renewals owing to

pressure of business or obsolescence of machinery installed for war purposes only should be provided for by the special modifications referred to in item 6. Apparently this would take the form of an increased allowance for expenses before the profits are arrived at, and the profit thus arrived at would then be subject to the usual allowances for wear and tear.

9. The definition of "capital" will, no doubt, give rise to considerable dispute, but the meaning of the definition attached to the Act would appear to confine capital to something for which cash has been paid, or for assets which are material and tangible and which were necessary to earn the profits under review. Briefly, capital consists of the following:—

(*a*) The price at which the assets were acquired, less wear and tear, or unpaid charges.

(*b*) Debts due to the trade.

(*c*) Profits employed in the business.

(*d*) If the assets have been paid for otherwise than in cash, the price is the consideration at the time the asset was required.

(*e*) Where a trade or business has been converted into a company, and the shares wholly or mainly held by the person who was the owner, no value is to be attached to these shares so far as they are represented by goodwill or any other items which are not material assets of the company. Patents and secret processes are deemed to be material assets.

N.B.—The intention is obviously to avoid the inclusion of watered capital.

10. Some question has been raised as to directors' fees, which must not exceed the sums allowed in the last pre-war trade year, but the Commissioners have power under special circumstances to direct otherwise.

It is presumably not the intention of the Revenue to entirely deprive managing directors of the additional fees which they may have earned during the war period.

This proviso has apparently been made with the intention of guarding against undue allowances being made to managers and managing directors.

11. In arriving at the profit no deduction is to be made for income-tax or excess duty. Any charges for income-tax (Schedule D) on excess profits is to be adjusted in assessing under Schedule D, and if this is impracticable when assessing this tax, the amount at which the income-tax would have been reduced can be deducted from the amount payable for excess profits duty.

In other words, the question of paying income-tax on excess profits duty is a matter for adjustment after the excess profit has been ascertained.

12. Section 44, sub-section 2, provides that "it shall be the duty of every person chargeable to excess profits duty to give notice that he is chargeable to the Commissioners of Inland Revenue before January 31, 1916."

This is an amendment of the Bill which gave December 31 as the date.

N.B.—There appears to be no obligation on the part of the Inland Revenue to send out any special notice. A general notice has been issued in the Press to the effect that persons chargeable should notify the Commissioners of Inland Revenue, Somerset House, W.C., or advise their Local Surveyor of Taxes.

The following formal notice should suffice:—

"EXCESS PROFITS DUTY.

"We beg to inform you, in accordance with Section 44 (2) of the Finance (No. 2) Act, 1915, that it is possible on investigation our accounts for the accounting period in question may reveal liability to the above duty."

CONTROLLED ESTABLISHMENTS.

It would appear from the Act that the excess profits of these establishments are liable to duty.

THE INSTITUTION OF ELECTRICAL ENGINEERS AND ALIEN ENEMIES.—The Council of the Institution of Electrical Engineers have passed the following resolution:—"The Council are of opinion that Clause 41 of the Articles of Association provides sufficient means for the expulsion of undesirable persons (whether alien enemies or not) from the Institution consistently with making the thorough investigation of the circumstances of each case, which is essential in order to avoid the risk of doing grave injustice to individuals." The Council have also under consideration the question whether the Institution should obtain further powers for the expulsion of alien enemies.

BUSINESS IN ENGINEERING.—In the course of an interesting paper under the above title, which he read before the Junior Institution of Engineers on the 10th inst., Mr. F. G. Hatch stated that engineering, as we know it to-day, could not exist without its commercial side. The young engineer too often thinks that all engineering matters should be regarded as having only technical interest, and that commercial considerations are beneath the notice of the engineer. Abstract science is of very little value to the everyday world until it has been commercialised in some form or another. Of what value to the world at large would Stephenson's invention of the locomotive have been if, after he had made his first engine, it had been described in papers, examined by learned professors, looked upon as an interesting novelty, and—allowed to rust? Its value to mankind became apparent and real when it was seen to open up a new era in transportation, when commercial men advanced the money to build a railway, by means of which it was demonstrated that goods were hauled cheaper and quicker than had previously been possible. Stephenson himself had probably little idea of the commercial possibilities of his work, but if his invention had not stood the commercial test in addition to the practical working test, we should not have had the railway as we do have it to-day.

ELECTRIFICATION OF THE MANCHESTER TO BURY SECTION OF THE LANCASHIRE AND YORKSHIRE RAILWAY.

(*Continued from page* 30.)

AT the end of the station are arranged stores, offices and switchboard platform. The stores are alongside the main entrance on the basement floor, and immediately above them on the turbine-room floor are arranged the offices for the operating staff. The control switchboards are placed on a gallery above the offices, overlooking the turbine-room, and the control-wire is accommodated in the cable-room between the ceiling of the offices and the switchboard gallery.

The arrangement of the switchboards on the control platform is shown in Fig. 23, on page 53. There are three separate boards:—

1. The main control-board for operating the main units and feeders.

2. 440-volt alternating-current board operating the station auxiliaries.

3. Direct-current board controlling the control-circuits, lighting, cranes and stand-by battery for the control-circuits.

Switch-Gear.—The switch-gear, manufactured by the British Thomson Houston Company, is of the solenoid-operated remote-control type. The main switch-gear is housed in a separate building, access to which is obtained by a foot-bridge from the turbine-room floor. The switch-house consists of a four-storey building, on the ground floor of which is housed the battery, consisting of seventy cells. The first floor is the cable-room, the second floor the switch-room, and the third floor the bus-bar room.

A cross-section and a part elevation of the switch-house are shown in Figs. 24 and 25 respectively, on page 53. The control-board on the gallery consists of thirteen panels, on which are mounted the necessary equipment for controlling the main switch-gear for the two 5000-kw. generator equipments, with two blank panels for future extensions; five 300-kw. feeder equipments, two 250-kw. transformer equipments, one test feeder equipment, and one synchronising equipment.

The 440-volt three-phase switchboard consists of five panels, on which are mounted hand-operated oil-switches and the necessary gear for controlling two 250-kw. transformer equipments, one 500-kw. generator, two rotary converter equipments, and two feeder-panels. The direct-current board consists of five panels, two controlling the direct-current side of the rotary converters, one the 125-volt battery, and two feeder-panels for the main control, lighting, and crane motors.

The main switch-gear in the switch-house is contained in cells built up of moulded stone (see Figs. 26 and 27, page 53), each phase being separated throughout with barriers of the same material. The bus-bars with the bus-bar isolating-switches are placed on the floor above the switch-room, the cell construction being of a similar character to the above. The fronts of the cells are covered by expanded-metal sliding-screens, these screens being interlocked with isolating-switches, so that it is impossible to open out any cell until the isolating-switches controlling the apparatus in that cell have been opened. The cells containing the oil-switches, which are shown in Fig. 27, have metal doors, which are not interlocked.

The main cables are suspended from the foot-bridge which gives access to the switch-room, and enter the cable-room immediately beneath the switch-room, being taken up to their respective cells as required. The outgoing feeders are carried from their respective cells and supported by insulators from the ceiling, passing through the wall of the switch-house, by means of leading-in tubes, to the overhead line outside.

The bus-bars are in duplicate, and so arranged that any machine, or any set of feeders, can be connected to either set of bus-bars; but no machine, or no particular set of feeders, can be connected to both sets of bars at the same time, the isolating-switches for the bus-bars being interlocked to prevent this. By this means one set of bus-bars can be used for power purposes, whilst the other at the same time can be utilised for general test purposes.

The order of the cells is exactly the same as that of the control switchboard. The main oil-switches are operated by means of "pull-type" switches on the control-board, which energise relay switches mounted on the oil-switch. The use of relays is done in order to restrict the size of the cable required between the control-board and the switch-gear. An indication of the position of the switch is given by red and green lamps, which are placed vertically above and below the "pull-type" switch. The controlling-switch for the lamps is operated by the movement of the oil-switch itself. The voltage of the control-current is 125. A throw-over switch is provided on the synchronising panel, by means of which an emergency excitation can be brought into operation should the exciters fail. This excitation current is regulated by means of a rheostat, which is mounted immediately behind this panel. With the switch-gear a system of balance protective gear has been provided for the turbo-alternators and the station transformers. This is operated by means of current transformers and relays. Should a fault occur between phases, or between any phase and earth, these relays operate and trip the main oil-switch. In addition, automatic field-switches are provided for the turbo-alternators. These open the field circuit automatically when an internal fault occurs in the turbo-alternator, which at the same time operates the protective gear and trips the main oil-switch.

In normal running, the station auxiliaries will be worked through two station transformers of 250 kw. each, manufactured by the British Transformer Company, of Heyes, converting from 6600 to 440 volts, three-phase, and enabling the 500-kw. auxiliary set to be shut down. During periods of very light load, such as lighting of stations during the night time, the auxiliary set can be run alone, and the voltage raised through the same transformers to 6600 for transmission to the various stations or goods yards. The direct current at 125 volts is obtained by means of two rotary converters operating through transformers from the 440-volt supply. Each of these converters has a capacity of 50 kw., and they were made by the British Westinghouse Company. They are used in conjunction with a 70-cell battery (made by the Chloride Electrical Storage Company, of Clifton Junction) and a small booster. All drainage from the station is treated by a drainage plant situated at some distance from the building. After treatment the drainage is dealt with by means of a vertical-spindle "Sunturbo" pump, manufactured by Messrs. Peter Pilkington, Limited, of Bamber Bridge, near Preston. This pump is capable of dealing with 80,000 gallons of water per hour, against a total head of 32 ft., when running at a speed of 715 revolutions per minute, and is driven through vertical shafting by a four-pole 20-horse-power three-phase motor. The weight of the combined set is 1¼ tons, approximately.

HIGH-TENSION TRANSMISSION LINE.

Two main feeder lines are used to convey the power from Clifton Junction power-station:—

1. The north line, 4 miles long, runs from the Clifton power-station to Radcliffe sub-station *via* Ringley-road.

2. The south line, 4¼ miles long, runs from Clifton power-station to Manchester, Victoria sub-station, *via* Pendleton New.

Both these feeders are of the same capacity, and consist of overhead conductors, of three cables in duplicate, and three-core cables, paper-insulated, lead-covered, and armoured with steel galvanised wires, in duplicate. The overhead cable, supplied by the British Insulated and Helsby Cables, Limited, Prescot, and Messrs. Thomas Bolton and Sons, Limited, consists of 7 to 10 S.W.G. per phase; the three-core of 19 to 14 S.W.G. per phase was manufactured by Messrs. W. T. Henley's Telegraph Works Company, Limited, of London. The outer diameter of the three-core cable is 2.293 in., the armouring 0.1 in., and the thickness of the lead 0.14 in. The joints are of the plumbed "lead-sleeve" type, and the conductors are insulated with paper sleeves, the boxes being filled in with compound. The north line is practically all overhead, cable only being used when passing under public bridges. The south line consists of 1¼ miles of overhead and 3¼ miles of cable. The overhead is carried throughout on "H" poles, the conductors being arranged three on each side of one pole, the other being left for future extensions. The standard span used is 70 yards. The three-core cable is carried on posts, and where convenient on wall brackets. Both lines are in duplicate, and under ordinary working conditions will both be in use.

The "H" poles consist of two fir poles of an average diameter of 10 in., 6 ft. from the butt. The cross-arms supporting the insulators are of channel iron, 4 in. by 2 in. by ¼ in., clipped on to the pole. The pole is also braced with wooden struts and bolts, but no anchor-stays are used except at points where the line makes an angle. The whole of the armouring, and also the iron-work on the poles, is earthed to copper earthing-plates at quarter-mile intervals. No lightning-arresters are used, but at the points where the cables enter the power-station and sub-stations, choking coils are provided.

SUB-STATIONS.

There are two sub-stations, situate at Manchester (Victoria Station) and Radcliffe, and Fig. 28, page 56, shows a diagram of the transmission from the power-station to the sub-stations, and thence to the live rail. Each sub-station is a combined rotary and battery sub-station, the equipment in each being identical, though the arrangement at Manchester is modified slightly, due to its being placed in an existing building.

Rotaries.—Each sub-station is equipped with three rotary converters, manufactured by Messrs. Dick, Kerr and Co., Preston (see Fig. 30, page 57), of 1000 kw. six-phase, 25 cycles, 10 poles, 300 revolutions per minute. The overload capacity of each is 100 per cent. momentarily, and they can be run continuously at 25 per cent. overload. They are arranged with an induction motor on the end of the main shaft for starting and self-synchronising. No arrangements for starting from the direct-current side are provided. Three transformers, also supplied by Messrs. Dick, Kerr and Co., are used for each rotary converter, each 350 kv.a., and wound for a ratio of 6600 to 900. They are of the oil-cooled type, and enclosed in sheet-steel welded cases fitted with external tubes for radiating the heat and circulating the oil. The tubes are welded into position, and this gives a perfectly oil-tight case.

The terminals for both primary and secondary leads are brought up through porcelain insulators at the top of the case, and connections are made on the high-tension side through short leads and trifurcating boxes to the three-core cables from the high-tension switch-gear. The low-tension leads are taken to the starting pillar and thence to the rotary. The diagram of connections is shown in Fig. 31, page 57.

Battery.—An "Entz" booster of the automatic reversible type, with carbon regulator, made by Messrs. Mather and Platt, Limited, for the Chloride Electrical Storage Company, is installed in the rotary-room. This consists of three continuous-current machines—booster, motor and exciter—coupled together and mounted on one bed-plate, giving an output of 900 amperes, 185 volts continuously, and will give 2000 amperes at 190 volts for 15 seconds. Its output for charging the battery is 300 amperes at 300 volts continuously, and the voltage

ELECTRIFICATION OF THE MANCHESTER TO BURY SECTION; L AND Y. RAILWAY.

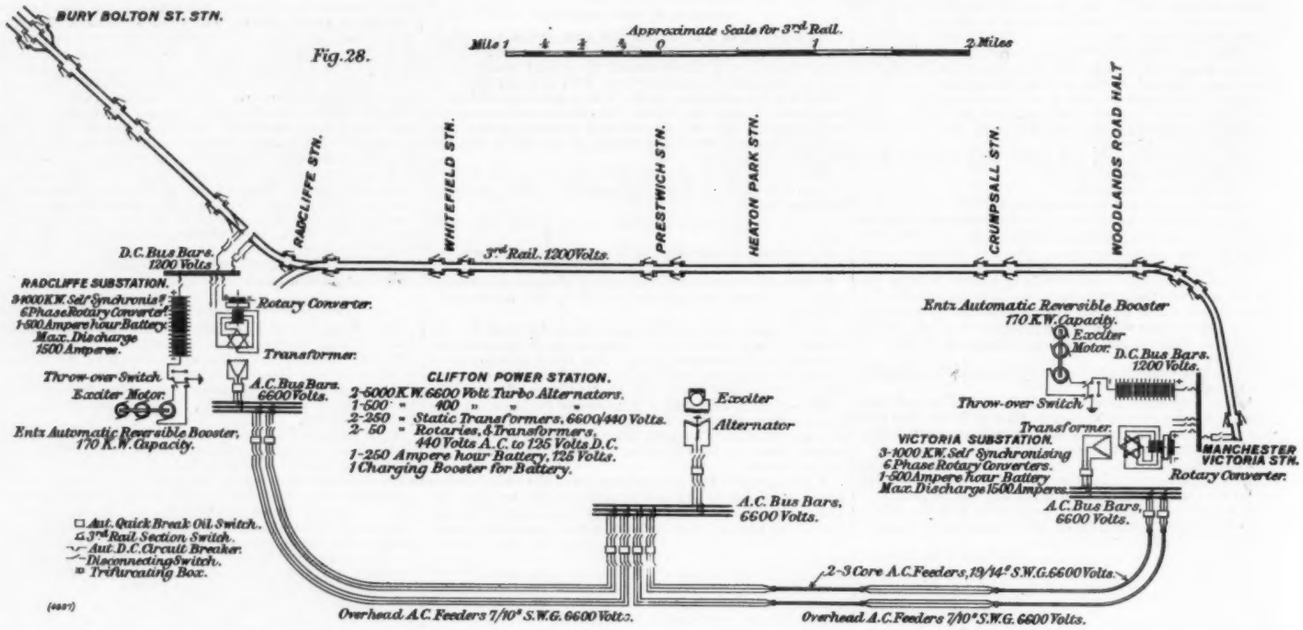

BURY BOLTON ST. STN.
Approximate Scale for 3rd Rail.
Miles 1 4 3 2 1 0 1 2 Miles
RADCLIFFE STN.
WHITEFIELD STN.
PRESTWICH STN.
HEATON PARK STN.
CRUMPSALL STN.
WOODLANDS ROAD HALT
3rd Rail. 1200 Volts.
D.C. Bus Bars. 1200 Volts.
RADCLIFFE SUBSTATION.
3-1000 K.W. Self Synchronising 6 Phase Rotary Converters.
1-500 Ampere hour Battery. Max. Discharge 1500 Amperes.
Rotary Converter.
Transformer.
Throw-over Switch.
Exciter Motor.
A.C. Bus Bars. 6600 Volts.
Entz Automatic Reversible Booster. 170 K.W. Capacity.
CLIFTON POWER STATION.
2-5000 K.W. 6600 Volt Turbo Alternators.
1-500 " " "
2-250 " Static Transformers, 6600/440 Volts.
2-50 " Rotaries, 6 Transformers, 440 Volts A.C. to 125 Volts D.C.
1-250 Ampere hour Battery, 125 Volts.
1 Charging Booster for Battery.
Exciter
Alternator
A.C. Bus Bars, 6600 Volts.
Aut. Quick Break Oil Switch.
3rd Rail Section Switch.
Aut. D.C. Circuit Breaker.
Disconnecting Switch.
Trifurcating Box.
Entz Automatic Reversible Booster. 170 K.W. Capacity.
Exciter Motor.
D.C. Bus Bars. 1200 Volts.
Throw-over Switch.
Transformer.
VICTORIA SUBSTATION.
3-1000 K.W. Self Synchronising 6 Phase Rotary Converters.
1-500 Ampere hour Battery Max. Discharge 1500 Amperes.
Rotary Converter.
MANCHESTER VICTORIA STN.
A.C. Bus Bars, 6600 Volts.
2-3 Core A.C. Feeders, 19/14² S.W.G. 6600 Volts.
Overhead A.C. Feeders 7/10² S.W.G. 6600 Volts.
Overhead A.C. Feeders 7/10² S.W.G. 6600 Volts.

Fig. 28.

FIG. 28. DIAGRAM OF ELECTRICAL CONNECTIONS: POWER-STATION TO SUB-STATIONS AND TRACK.

can be raised to 400 for over-charging. These latter ratings are obtained by hand regulation. The booster is shunt-wound, and is excited from the exciter for automatic working, and from a portion of the battery for hand-regulation. The exciter is shunt-wound, and is separately excited from a portion of the battery. Its excitation is controlled by means of an automatic carbon regulator connected up on the principle of the "Wheatstone Bridge," and operated by the main generator output. The exciter is capable of exciting the booster fully when the latter is doing its regulating work.

In order to prevent a lag in reversing, the exciter is designed to give three times the excitation voltage necessary to give the required boost, and the carbon regulator automatically throttles the excess current when the correct boost has been reached. The motor is capable of driving the booster at all loads when running off a 1200-volt circuit at the speed of 520 revolutions per minute. The speed can be raised to 650 by means of a shunt-regulator, in order to obtain the over-charge voltage. The set is provided with a device suitable for breaking the circuit of the motor when the speed of the set exceeds a definite amount. All the cables from the switchboard to the rotaries, transformers, boosters, &c., are carried in concrete ducts in the flooring of the sub-station. These ducts are covered in by steel non-slip plates. The battery, which is housed in a separate building outside the rotary building, consists of 580 "Plantide" cells, manufactured by the Chloride Electrical Storage Company, Clifton Junction. The capacity is 500 ampere-hours on the one-hour rating, and the charging current can be raised to 1500 amperes for fifteen seconds. Each cell is contained in a pitch-pine box lined with sheet lead, and this box is of such a size that the capacity of the battery can be increased ultimately to 800 ampere-hours by the addition of more plates. The positive plates are of the "formed" type, and the negative plates are of the "box" or "cage" type, each plate consisting of an "antimonial" lead cage in halves, riveted together. The plates are perforated and the active material held in pockets. The plates are separated by wooden dowels, which also act as a support, and are suspended on stout glass slabs resting on the bottom of the cell. The stands are of pitch-pine, protected by anti-sulphuric paint, and are supported on strong porcelain insulators. Each battery is divided into two portions, which are connected through an isolating switch. The high-voltage portion (600 to 1200) is partitioned off by wooden railings with gates, which are kept locked, so that access can only be obtained by authorised persons. The cells of this portion are protected by wooden rails mounted on insulators; wooden gangways, which are also mounted on insulators, are placed between the cells. This arrangement has been carried out to prevent accidental shock of over 600 volts. When it is required to carry out work on this portion of the battery the isolating switches are used, which reduces it to the same condition as the low-voltage half.

A combined charging and milking booster (manufactured by Messrs. Mather and Platt for the Chloride Electrical Storage Company), for the battery is also installed in the rotary-room, and consists of two continuous-current machines—one motor and one generator—coupled together. This set is capable of charging the cells, fifty in number, which are connected to the "Entz" booster, in two hours a day, charging twenty-five cells at a time, and giving 45 amperes at 40 to 70 volts. The motor is suitable for working on a 1200-volt circuit, and the booster is arranged for exciting from the cells to which the "Entz" regulator is connected. The set is also capable of milking the cells with an output of 200 amperes at 2 to 14 volts.

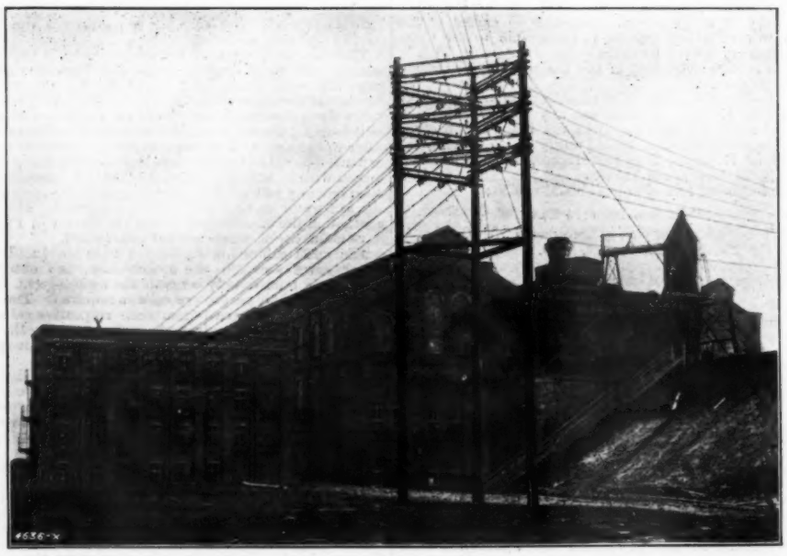


FIG. 29. POWER-STATION AND OUTGOING TRANSMISSION LINE.

Switch-Gear.—The switch-gear (see Figs. 32 and 33) has been supplied by the British Thomson Houston Company, Rugby, and is in two parts, one of the "cubicle" type controlling the high-tension feeder and transformer leads, and the other of the "flat-board" type controlling the direct-current rotaries, battery, booster and live rail. Both boards are placed on the ground floor of the station. The high-tension apparatus is contained in six cubicles, No. 1 and 2 controlling the duplicate feeders, No. 3 being the bus-bar potential feeder, and Nos. 4, 5 and 6 controlling the transformers for the three rotary converters. The feeder and high-tension cubicles each contain a hand-operated oil-switch, the connections to the bus-bars being made through switch-clips at the back. The arrangement is such that the whole of the apparatus can be withdrawn from the cubicle for inspection purposes, interlocking devices being used to prevent the apparatus being withdrawn or replaced when the oil-switch is closed.

The direct-current board, being 1200 volts, is arranged so that there is no live contact on the front of the board, the main switches and circuit-breakers, and all 1200-volt apparatus, being placed above the board in cubicles divided from each other by partitions (see Fig. 33). This board consists of fifteen panels, 14 ft. to 15 ft. high. All the switch-gear is mechanically operated by insulated levers on the lower panels. The rotary panels each include a circuit-breaker, a single-pole quick-break switch, a field ammeter, a main ammeter and rheostat. The total-output panel includes an integrating wattmeter and a main ammeter. The feeder panels are two in number; one controls the live rails on one side of the station, and the other the live rails on the other side of the station. The up and down live rails in each case are independently controlled by a knife-switch, but one circuit-breaker governs both up and down live rails in one direction. The battery-booster panels contain the necessary switch-

ELECTRIFICATION OF THE MANCHESTER TO BURY SECTION; L. AND Y. RAILWAY.

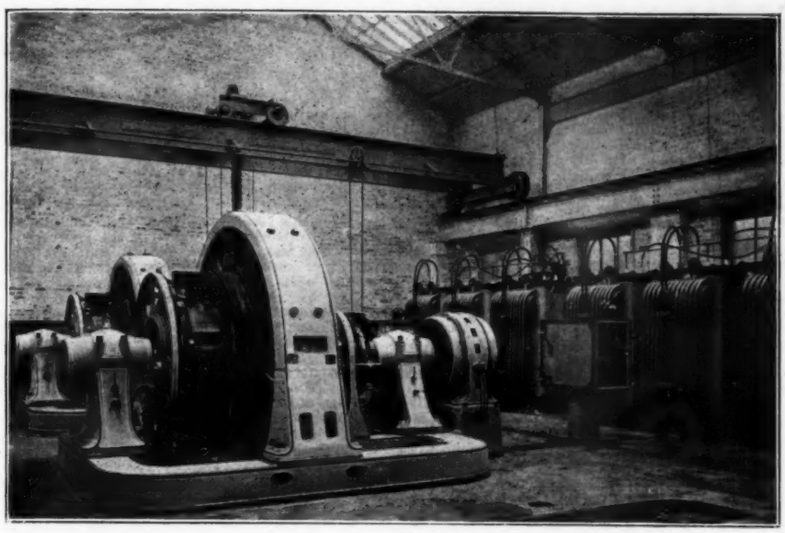


FIG. 30. 1000-KW. ROTARY CONVERTERS AND TRANSFORMERS IN SUB-STATION.

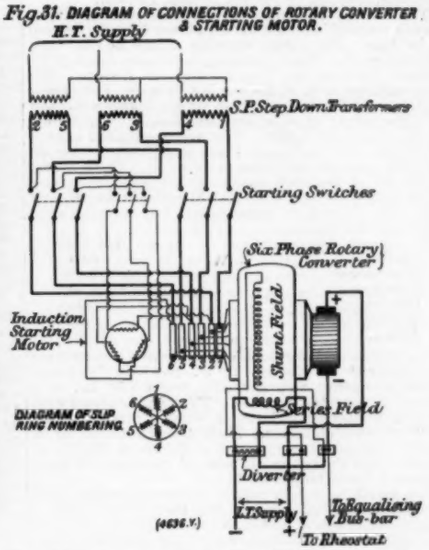


FIG. 31. CONNECTIONS OF ROTARY CONVERTER AND STARTING MOTOR.

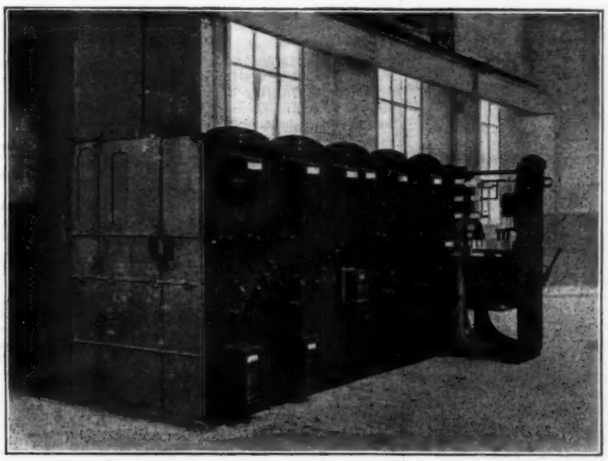


FIG. 32. ALTERNATE-CURRENT SWITCHBOARD.

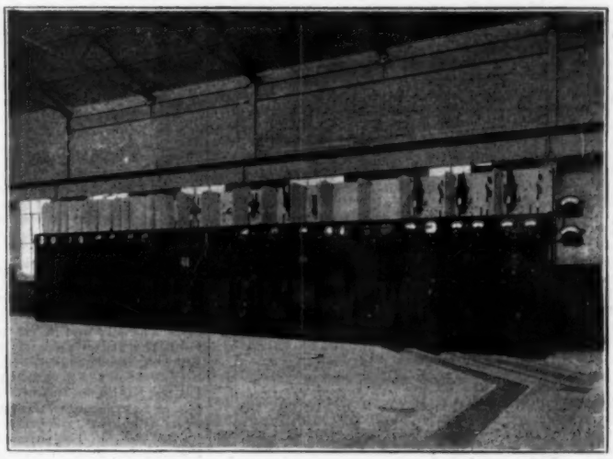


FIG. 33. DIRECT-CURRENT SWITCHBOARD.

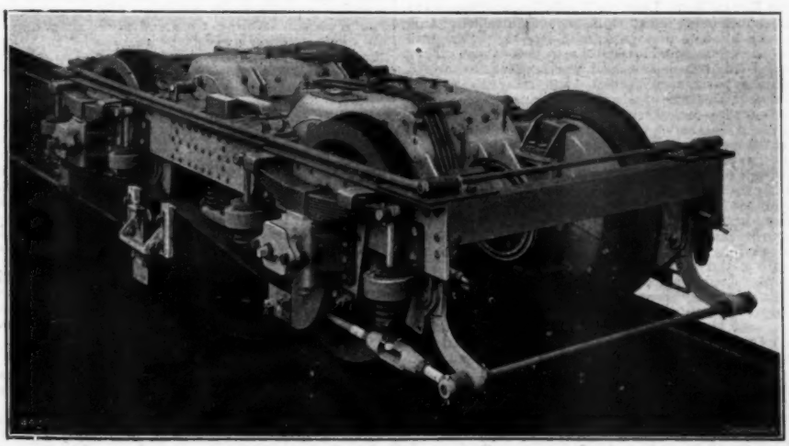


FIG. 34. MOTOR-BOGIE WITH CONTACT-SHOE.

gear for operating the booster and the main battery, also the milking-booster.

TRACK.

Though the system adopted is the third or live rail, with track return augmented by a fourth rail, considerable departure has been made from the previous practice in that it is a side-running contact instead of over or under-running. This has been brought about by the fact that 1200 volts, which is the maximum voltage allowed on third or live rails, necessitates more adequate protection against shock, and the form of rail adopted is admirably adapted for guarding. This, of course, also applies to the under-running type, but here the objection was the small clearances available. The live rail and its guarding, also its relative position to the track-rails, as shown in Figs. 35 to 42, page 60, is the invention of Mr. J. A. F. Aspinall, the general manager of the railway company. It is very compact, lies close to the running rail, and gives the maximum space for platelayers and other workmen in the six-foot where the rails are normally fixed. The guarding is of Jarrah, which has been adopted for its non-combustible qualities, and is arranged as shown in Figs. 35, 36 and 42. It is held in position by clips secured by ordinary chair-keys, no screws or nails being used. The section of the rail has been designed so that its centre of gravity is well within the base line.

The rail has been supplied by the Shelton Iron, Steel and Coal Company, Limited, Stoke-on-Trent, of a special design. The arrangement is such that a projection on the upper portion of the insulator acts in conjunction with the guarding as a key which keeps the rail in position. The insulator itself is kept in position by three

small brackets. The rail, however, does not rest directly on the porcelain insulator, but a wooden packing is inserted between to act as a buffer. The normal spacing of the insulators is approximately 12 ft. The live rail is anchored every 100 yards by a specially-designed anchor insulator, supplied by Messrs. Bullers, Limited.

The live-rail insulators are of white porcelain, completely vitrified throughout and glazed all over, and are 6¼ in. high. The actual creeping surface is 8 in. from metal to earth. These insulators have been supplied by Messrs. Doulton and Co., Limited, of London. The cross-sectional area of the rail is 8.35 sq. in., and weighs 85 lb. per yard. Its resistance ranges between 6.5 and 7.0 times copper of equal area and length. The normal length of each rail is 60 ft. The rails are bonded at each joint with two bonds per joint, each bond having an effective cross sectional area of 0.4 sq. in. These bonds, which are of the strip-copper flexible type, have been manufactured by the Forest City Electric Services Supply Company, Limited, of Manchester. The chemical composition of the rail is—

	Per Cent.
Carbon	0.08
Phosphorus	0.034
Manganese	0.22
Sulphur	0.026
Silicon	0.022
Iron	99.618

The cables used for connecting across the gaps were manufactured by Messrs. T. W. Henley's Telegraph Works Company, and, normally, two 0.5 sq. in., or a single 1 sq. in. cable, are used. They are insulated with vulcanised bitumen, and run in wooden troughs, which are filled in with bitumen. These troughs are, as far as possible, carried above ground, as shown on the left of Fig. 38, page 60, but in all cases of underground work "Howard" troughing is used.

The fourth or return rail is of square section with rounded corners, and weighs 88.5 lb. per yard, with a cross-sectional area of 8 84 sq. in. The chemical composition and electrical conductivity are the same as the live rail. This section has been adopted on account of the small surface exposed over a given volume of rail, and therefore small maintenance in painting, &c. This rail is also cut in lengths of 60 ft., and is placed between the running rails. It rests on wooden pads, 1 in. thick, secured to the sleepers by iron dogs, and is anchored at intervals of 100 yards. There are two bonds per joint, and the effective cross-sectional area is 0.325 sq. in. per bond. The fourth rail is also cross-bonded every 100 yards to the track rails with cable-bonds of 37/15 S.W.G. copper, and the track rails are also bonded by cable-bonds.

Figs. 37 and 38, page 60, show the general appearance of the live rail and its relation to the track. The track is fed from the sub-stations through short feeders, which take the shortest course from the sub-station to the track rails; no supplementary feeders are used. The live rail is divided up into sections, which are connected through section switches placed alongside the live rail, and operated as ordinary hook switches. At all gaps the live rail is ramped towards the running rail so as to receive the shoe which runs on the outside of the rail. This ramp is shown in Fig. 37. The whole of the erection of the track equipment has been carried out by the railway company.

Shoe.—The general arrangement of the shoe is shown in Figs. 39 and 40, page 60, while a section through the shoe is given in Fig. 41. The connection of the shoe to the trolley cable is shown clearly in Fig. 42. The mounting of the shoe on the bogie is shown in Fig. 34, on page 57.

(To be continued.)

AUTOMATIC SHELL-BAND HEATING FURNACE.—A brief illustrated description is given in the *American Machinist* of the 15th inst. of an automatic shell-band heating furnace, built by the August Muffle Furnaces, Limited, Halifax. It is stated that eight copper bands can be heated per minute for 4.5-in. high explosive shells, with a consumption of 3 cwt. of gas-coke per 12 hours. The copper bands are fed in the furnace automatically at the top through three slots, and owing to the rocking motion imparted to the furnace, they travel downward in a zig-zag course to the discharge ovens. The furnace can be heated either by solid fuel or by gas to suit the requirements; the heat travels upwards around each side of the working chamber without coming into contact with the work itself. All the bands receive exactly the same amount of heat treatment.

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.—The 132nd half-yearly report of the working of the Great Indian Peninsula Railway for the half-year ended September 30, 1915, showed an increase of 76.75 miles in the open mileage worked during the half-year under review, due to the Cawnpore-Banda Railway having been taken over from the Oudh and Rohilkhand Railway on April 1, 1915, and to other small adjustments. The following is a summary of the mileage worked at the close of the half-year :—

Quadruple line	21.00
Double line	650 90
Single line, including State lines	2386.16
Total	3058.06
In addition—	
Foreign lines over which running powers are exercised	62.17

With an increase of Rs. 24,63,862, or 6 40 per cent., in the gross earnings, there was a decrease of Rs. 29,82,039, or 9.87 per cent.. in the expenditure, the result showing an increase of net earnings amounting to Rs. 54,45,901, or 65.80 per cent., as compared with the corresponding period of 1914.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, January 5.

THE first week of the new year has not developed any thing new, but the momentum of past events is sweeping business into all the industries. Steel mills are working to a capacity thought impossible six months ago; starting in at 35 per cent. of capacity, prices advanced 2 dols. to 3 dols. a ton within six months. During the last half-year anticipated capacity was exceeded, prices averaging an advance from 12 dols. to 15 dols. a ton, with a present accumulation of business that will absorb the greatest possible production for at least six months; orders are now coming in for the third quarter. Production of steel in 1915 was about 28 million tons of finished steel, ingot production close to 30 million tons, pig-iron production about the same; but at present it is at the rate of 38 million tons, with a possible 40 million tons when certain obstacles are overcome; while expansion of pig-iron capacity is mooted, no attempt will probably be made beyond completing present improvements. Another general marking up of prices is probable this week, especially ingots, bars, plates, and shapes, from 1.80 to 2, after which the books for the third-quarter delivery will be thrown open.

There has been very little shutting down for repairs; the present embargo on freights holds up deliveries; congestion at terminals is an ugly problem, it is likely to become more serious; there might as well be a blockade of our ports. December bookings of orders were about 700,000 tons less than for November. There will soon be a scramble for bookings of orders for the last half of the year. Freight rates are enormous. There is practically no American merchant marine. Railroads report enormous business. Corporation dividends for distribution this week will exceed 300,000,000 dols; the bulk of this will immediately seek reinvestment, for which opportunities are rather limited. Abnormal industrial activity prevails throughout the eastern section of the country. Automobile motors are in extraordinary demand. Total exports from New York last week in value were 33,000,000 dols., or over double the previous year's average. It is fortunate the winter season does not permit such an enormous expenditure of munitions. The French Government has just ordered 2000 more cars in addition to 5000 placed last Thursday; the former order going to Canada. Foreign orders for bars and billets are crowding in faster than they can be taken, but apparently exorbitant prices and limited delivery facilities causes much of this business to hang fire. General business is at top notch. Time is now the great factor in war prosecution. Domestic buying is becoming a more and more important factor. Requirements are piling up, and as much as possible will be held in check until the expenditure of this coming summer of mountains of ammunitions.

METALLIC PERMANENT-WAY.—The value of the exports of metallic permanent-way from the United Kingdom shows no important changes, but it is still declining, as a consequence of the dislocation of foreign and colonial railway enterprise by the great war. The largest deliveries last year were made to British India, but their value fell to 284,238*l.*, as compared with 342,310*l.* in 1914, and 540,076*l.* in 1913. The expression "metallic permanent-way" includes chairs and metallic sleepers.

WILLING'S PRESS GUIDE.—We have received a copy of this guide for 1916, the forty-third annual issue. It is published at the price of 1s. by Messrs. James Willing, Limited, 125, Strand, London, W.C. It gives an alphabetical list of the newspapers and periodicals issued in the United Kingdom, the information including the indication of the year when the journal was founded, the day on which it appears, the price, and the name and address of the publishers. The papers are also classified according to the interests, trades, denominations, &c., which are served. Special indexes give the names of the London and Provincial publications. General information is also given on the Colonial, American, and foreign publications.

THE ROYAL NAVY LIST, OR WHO'S WHO IN THE NAVY.—Instead of being issued three or four times per annum, this publication is now an annual one, and in this form proves a very acceptable addition to year-books. There is issued this month a special war supplement, which, in addition to the usual tabulated list of flag officers and a record of the services of all officers, arranged according to alphabetical order of surname, gives a well-prepared epitome of the naval events during the war, a special record of the war services of the officers and the services of each ship, &c., with a diary of the events of the war connected with the Royal Navy. It will thus be seen that, both as a history and as a book of reference, this annual justifies its place amongst the many publications connected with the war. In addition, there is much further information brought up to date from previous publications, so that the organisation of the Navy and Admiralty and the work of the Fleet from the beginning of British naval history can be understood from the records. Only frequent reference can prove the accuracy of the information, but a cursory glance over the book shows the surprising error of Sir Henry Oram's name being starred, to indicate that he has retired, whereas he is still as active, vigorous, and originative as ever, as Engineer-in-Chief of the Fleet. We think, also, that it is unjustifiable that executive flag officers and the officers of the Royal Marine force are given in tabular order, whereas there is no such record of the engineering officers of the Fleet. With this addition the book would certainly be more complete. It is published at 7s. 6d. by Messrs. Witherby and Co., 326, High Holborn, London.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—The pig-iron market remained quiet on Wednesday afternoon, little business being done, with closing sellers' prices at the morning's level. Thursday morning's market was characterised by a certain narrowness of tone, cash warrants fluctuating between 78s. 3d. and 78s. 1½d. per ton, while one month's iron still remained, even at the close, at 78s. 9d., a turnover of 3500 tons being done. For cash warrants, sellers quoted 78s. 2½d. per ton at the close. Business firmed up at the afternoon session when an advance of from 3d. to 4½d. per ton was recorded, cash iron rising at the close to 78s. 7d. and one month to 79s. 1d. per ton. This temporary advance was not maintained on Friday, when prices dropped again at the forenoon market, the closing quotations, 78s. 5½d. cash and 78s. 10½d. one month, showing a decline of 1½d. and 2½d. per ton respectively. Business was done also at 78s. 11d. twenty-three days, and 78s. 6d. ten days, while the turnover reported amounted to 2500 tons. In the afternoon a certain dulness was apparent, and although 78s. 9d. was accepted for one month's iron, prices steadied a trifle at the close, when sellers quoted 78s. 6d. per ton cash and 78s. 11½d. one month, with 78s. 6d. fourteen days and 78s. 8d. twenty-four days. A further 2500 tons were dealt in. On Monday morning the market was firm, although the business was restricted. Cash iron alone was dealt in, some 1500 tons changing hands at 78s. 6½d. per ton, and at the close sellers quoted 78s. 8½d. cash and 79s. 2d. one month. At the afternoon session the tone was brisker, cash iron being bid up to 78s. 6½d. At this figure only one transaction was recorded, while the market closed with sellers' prices at 78s. 11d. cash and 79s. 5d. one month. The market opened firm yesterday (Tuesday) morning, and cash iron, after being dealt in at 79s. 2d., closed with sellers at 80s. On forward account Cleveland warrants fluctuated between 78s. 10½d. and 80s., finally closing with sellers at 80s. 3d. per ton. The transactions only amounted to 2500 tons A further advance was made in the afternoon, when a small business of 500 tons realised 80s. 5½d. one month. At the close sellers were quoted 80s. 2½d. cash and 80s. 8d. one month. Quite disconcerting was the reaction which took place in the market this (Wednesday) morning, when cash iron changed hands at 79s. 6d. per ton, sellers closing at this price and 80s. one month. Only 1000 tons were dealt in.

Sulphate of Ammonia.—The market for sulphate of ammonia continues strong, and things are much as they were a week ago, the price for prompt delivery, Glasgow, now being 17*l.* 17s. 6d. to 18*l.* per ton, and at Leith 18*l.* 5s. to 18*l.* 7s. 6d., a trifling advance over the previous week's quotations.

Scotch Steel Trade.—Considering the extraordinary amount of work put through by the steel-makers in the West of Scotland during the past fourteen or fifteen months, it is not surprising to learn that the Clyde area is now looked upon as the most important producing district in the country, from the standpoint of the Ministry of Munitions. The tension is intense, and there is every expectation that within the next few months the demands of our own and the Allied Governments will be considerably in excess of what they were last year. Steel for shell-bars is one of the most sought-after requirements, and the demand continues unabated. Although little mercantile business can be undertaken, the inquiries from France and a number of the Colonies are most promising. While the high cost of production has stimulated the constant rise in price during the past month or two, the fact that Government has now taken the price question into consideration, with the intention of fixing a maximum rate for all manufactured steel will, in a measure, relieve the tension. An increased Government control will, to a certain extent, limit profits, and if the wage question can be satisfactorily settled also, more normal conditions will soon prevail again. The matter is one of extreme difficulty, for each branch of the trade hangs so much upon the other, and those interested await the outcome of the negotiations with much concern. Several makers indicate a certain desire to withdraw prices altogether until the whole question is satisfactorily settled. Boiler-plates are still quoted 13*l.* 10s. per ton; ship-plates, 12*l.* 10s.; and angles, 13*l.* to 13*l.* 10s.—all less the 2½ per cent. for prompt delivery.

Malleable-Iron Trade.—In the malleable-iron trade the greatest activity still prevails, more especially on home account; indeed, were it possible, a much larger volume of business could easily be put through, for the demands are unceasing. As things are in the meantime, the bulk of the export business has to be passed over, simply because makers cannot deal with the numerous inquiries. The continued shortness of imported semi-finished material is having rather serious effect, and so also is the lack of good puddlers and other workers. This last-mentioned fact is responsible for the Coatbridge furnaces not all being in blast at the moment; those which are working, however, are in full operation all the time. With prices a trifle uncertain, "Crown" bars have slightly advanced during the week, and may now be called 13*l.* 5s. to 13*l.* 10s. per ton, less the usual 5 per cent. discount.

Scotch Pig-Iron Trade.—While the local demand for ordinary pig-iron is alike strong and steady, large quantities of hematite at the greatly increased rate of about 6*l.* 15s. per ton have passed from the hands of the makers to the iron and steel manufacturers engaged on extensive Government contracts, munitions, &c. With prices so very much in excess of those ruling in normal times, it is difficult to say what may happen, although it is hinted in certain quarters that higher rates are being

charged than are at all justifiable, and that to make money out of the nation's urgent necessity is unpatriotic in the extreme. Notwithstanding this, the high cost of raw material, the heavy freight charges, and the scarcity of labour, all help to send up prices, and as the required material must be forthcoming, there is no choice in the matter. There is no falling-off in the demand for ordinary foundry grades, despite the fact that upwards of 5*l.* per ton is being asked for some of the better brands of No. 3—practically a record price. There have been sixty-eight blast-furnaces in operation in Scotland during the past week, which is four more than in the preceding week, and five fewer than at the corresponding period a year ago. The current quotations for makers' (No. 1) iron show a steady increase, as the following figures indicate:—Clyde, Calder, Summerlee, and Langloan, 105s. per ton; Gartsherrie, 106s. (all shipped at Glasgow); Eglington, 100s., Glengarnock, 106s. (both at Ardrossan); Dalmellington (at Ayr), 99s. 6d.; and Shotts (at Leith), 105s.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Values of Cleveland pig-iron have this week touched higher rates than have ruled for over forty years. As much as 81s. has been realised for No. 3 g.m.b. Not since 1874, when 87s. 6d. was paid for the ruling quality, has 81s. been quoted. In 1873 the record price in the history of the trade was realised—viz., 120s. The position has now eased a little, and No. 3 is obtainable at 80s. 6d.; but sales are not being particularly pressed, as there is a prevailing opinion that the fixed maximum of 82s. 6d. will be reached very shortly. The other qualities of Cleveland pig were in the proportions that have ruled for some time past. No. 1 is in the neighbourhood of 83s. to 83s. 6d.; No. 4 foundry is 80s.; No. 4 forge, 79s. 6d.; and mottled and white iron, each 79s. All the foregoing quotations are for early delivery, very little disposition being shown to do business ahead to any extent.

Hematite Iron.—Very satisfactory accounts are given of the East Coast hematite branch of the staple industry. There are no stocks, production is taken up as fast as it is made, and quotations are very strong. No hematite is purchasable for supply before the second quarter of the year, and in fact there is little now offered for sale for delivery before July, many makers having disposed of the whole of their output to the end of June. There are substantial inquiries in the market on both home and Continental account, and with licenses for shipments to our Allies coming forward, more deliveries to France are reported. Nos. 1, 2 and 3 are fully 135s. delivered April next, and onward.

Shipments of Pig-Iron.—Under all the circumstances, shipments of pig-iron from the Tees are on a good scale. They would be heavier but for the shortage of labour. To date this month they average 1119 tons per working day, the total despatches amounting to 16,787 tons, as compared with total clearances of 29,450 tons, or a daily average of 1840 tons to the same date last month, and loadings of 10,135 tons, or an average of 675 tons per working day for the corresponding part of January a year ago.

Foreign Ore.—There is little new to report concerning foreign ore. Excellent supplies are coming to hand on contracts, so much so that consumers are accumulating a fair amount of stock, and for the time being, are not keen to buy. Sellers, however, are very well placed, and are not at all disposed to make concessions. Market rates remain on the basis of 38s. ex-ship Tees for Rubio of 50 per cent. quality. Freights, Bilbao-Middlesbrough, are fully 21s. 6d., and likely to be higher. Imports of foreign ore to Middlesbrough, so far this month, are officially returned at 131,880 tons.

Coke.—Business is passing in Durham blast-furnace coke, of average quality, at the fixed maximum of 28s. at the ovens, but a marked upward tendency is shown in rates of carriage, so much so that in some cases the quotation delivered at Tees-side furnaces is put at 32s., whereas the conveyance in normal times is not more than 2s. 6d. As much as 37s. f.o.b. is named for foundry coke, though the fixed maximum at the ovens is several shillings below that figure.

Manufactured Iron and Steel.—Finished iron and steel producers continue so busily engaged on Government work that private consumers experience much difficulty in obtaining deliveries, and it is almost useless attempting to transact ordinary commercial business to any extent. Quotations are steady, the following being among the principal market rates:—Common iron bars, 13*l.* 10s; best bars, 13*l.* 17s. 6d.; double best bars, 14*l.* 5s.; treble best bars, 14*l.* 12s. 6d.; iron ship plates, 11*l.*; iron ship-angles, 13*l.* 10s.; iron ship-rivets, 15*l.* 10s.; steel ship-plates 11*l.* 10s.; steel ship-angles 11*l.* 2s. 6d.; steel joists, 11*l.* 2s. 6d.; heavy steel rails, 11*l.*; and steel railway sleepers, 12*l.*—rails and sleepers net f.o.b., steel plates, steel angles, and joists net at works, and all other descriptions less 2½ per cent. discount.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—The strong position which has characterised the South Yorkshire coal trade is well maintained; every department is at full stretch. The cause of this is evident when it is realised that labour shortage has diminished the output by from 15 to 30 per cent., that munition and other controlled works are taking from 50 to 100 per cent. over their normal tonnage, and that practically every branch of industry is crying out for supplies. Were it not for the embargo placed upon shipments there would be an absolute famine. Merchants complain of the constant strain; many of them are thousands of tons behind on their contracts, and as men are still filtering away from the pits, there is not much prospect of improvement. The question of price has, to a great extent, been settled under the Coal Prices (Limitation) Act. Nuts and cobbles, largely used in furnace and boiler work, make 16s. to 16s. 6d. per ton, but if any of these came on the open market 1*l.* per ton would be readily offered for shipment. The only steady supplies which are leaving British ports are for France. Shipping requirements, however, are heavy, notwithstanding the restrictions. Small coal is a very strong market, there being practically no free supplies available. Coke plants are taking a large tonnage, working at full stretch, producing chemicals and other residuals required by the Government. In fact, the whole industry is approaching a controlled trade, as the Government are insisting on firms working on national work being kept well supplied. The latest quotations are:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best Silkstone, 17s. 6d. to 18s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. to 16s.; small nuts, 14s. 6d. to 15s. 6d.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 11s. to 12s.; seconds, 9s. 6d. to 10s. 6d.; smalls, 8s. to 9s.

High-Speed Steel.—Sheffield manufacturers of high-speed steel have met and accepted the prices and conditions laid down by the Government for the sale of this commodity. The following are the prices and conditions which it was explained must be strictly observed in all transactions connected with the sale of high-speed steel. Ordinary quality, approximately 14 per cent. tungsten, 2s. 10d. per lb. (basis); superior quality, approximately 18 per cent. tungsten, 3s. 10d. per lb. (basis) net cash, delivered at the customer's works with the following extras:—Rounds and squares, 3 in. to 8 in. inclusive, 4d. per lb.; ditto, under ½ in. to ¼ in., 3d. per lb.; flats, under 1 in. by ⅝ in. to ½ in. by ¼ in., and of sizes over four times in width over thickness, 3d. per lb.; bevels of approved sizes and sections, 6d. per lb.; bars cut to length, 10 per cent. extra; exceptional sizes and sections not covered in the above list subject to special quotation; oddment orders of less than 56 lb., of a size, 3d. per lb. extra. The above list of extras has been compiled to represent as nearly as possible the average practice of the trade. The prices quoted relate to the home trade only.

Iron and Steel.—The iron and steel trades of Sheffield are passing through a boom period such as has never before been experienced. Week by week, as additions are made to plant and accommodation, the output climbs above all previous records. Not only have there been large extensions of works, but the workers are exerting themselves to the utmost of their resources. Temporary accommodation is being provided for the thousands of temporary artisans who have been drafted into the works, and the Government are paying a substantial subsidy to the Corporation for the erection of workmen's dwellings to house the employees of the big works. In the iron market maximum prices of common irons have now been definitely fixed at 87s. 6d. for both Lincolnshire and Derbyshire forge on trucks, with 2s. 6d. extra for foundry qualities. At present there is considerable variation in the quotation, and limit prices have not been reached. Sales have been made in Lincolnshire foundry and forge at 85s., with basic qualities at 2s. 6d. above those rates. Derbyshire is making about 82s. on truck for foundry lots, and 80s. for forge. Uncertainty is still experienced respecting hematites, there being no material on the open market, and consumers are willing to pay big rates for immediate delivery. Overseas business is still a heavy feature, and includes orders for steel, saws, tools, shovels, cutlery, sheep-shears, and files. Tramway material is in a strong position, and orders on municipal account include tyres, manganese steel crossings, and special track work.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Owing to a scarcity of steam coal at Cardiff, there has been a decided advance in prices since the commencement of the new year. Second Admiralties and Monmouthshires have been making 32s. 6d. per ton at Cardiff, free on board. This is an advance of 15s. per ton upon prices paid in November. There is a prospect of extreme pressure for supplies of steam coal continuing, as a large number of vessels have been kept waiting for loading-berths, although tonnage has arrived to a substantial extent. Colliery outputs, although somewhat heavier, are still inadequate to meet current requirements; and sellers who have limited parcels to offer are still quoting higher prices. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have brought 31s. 6d. to 32s. 6d. per ton; best bunker smalls have made 17s. 6d. to 18s. 6d. per ton; and cargo smalls, 12s. to 15s. per ton. The best household coal has realised 23s. to 24s. per ton; good households have brought 21s. to 22s. per ton; No. 2 Rhondda large has been taken at 24s. to 25s. per ton; and No. 2 smalls have been quoted at 13s. to 14s. per ton. The latest quotation for patent fuel has been 28s. to 30s. per ton. Special foundry coke has made 42s. to 45s.; good foundry coke, 38s. to 42s.; and furnace coke, 32s. to 35s. per ton. As regards iron ore, Rubio has been quoted at 35s. to 37s. per ton upon a basis of 50 per cent. of iron, and charges, including freight, insurance, &c., to Cardiff or Newport.

Current Coal Shipments.—The exports of coal from Bristol Channel ports in December was 1,820,995 tons, showing a reduction of 290,933 tons, as compared with December, 1914. The cargo shipments of last month were:—Cardiff, 1,033,364 tons; Gloucester, 1949 tons; Llanelly, 9288 tons; Newport, 304,339 tons; Port Talbot, 91,631 tons; and Swansea, 315,246 tons, making a total for all ports of 1,755,817 tons. The principal market shipments were:—Cardiff, 243,824 tons; Newport, 416,666 tons; and Swansea, 34,732 tons.

Western Trade Matters.—There have been signs of activity at the Dowlais Works. The Goat Mill has been engaged upon a foreign order for heavy steel rails; the Big Mill has been busy with small orders for merchant firms, light rails for underground lines and sidings, fish-plates, and sole-plates. At the last sitting of the Swansea Harbour Trust, Mr. R. Beck reported that exports declined 18 per cent. last month, the decrease occurring in coal, coke, and patent fuel; the falling-off here was no doubt due to a scarcity of tonnage; tin-plate exports showed little change; rather less had been sent to Norway and Holland, but more had gone to Japan. The directors of the Mount Stuart Dry Docks, Limited, have distributed a dividend at the rate of 6 per cent. per annum upon the preferred ordinary shares; a dividend of 6 per cent. per annum has always been paid upon the deferred ordinary shares; the dividends are interim distributions for the half-year ended December 31. At a meeting of the Newport Town Council on Tuesday, Mr. Robjent proposed that a recommendation of the parliamentary and improvement committee that the United Tube Corporation should be allowed to take up a portion of the undertaking of the British Mannesmann Tube Company should be referred back for further consideration. It was pointed out that the main question was whether the council was prepared to assist the Government. The motion for postponement was defeated, only two votes being recorded for it. The Cynon Colliery Company reports a greatly increased profit for 1914-15. The results of the past seven years' working were as follow:—1908-9, 721*l.* profit; 1909-10, 11,821*l.* profit; 1910-11, 5146*l.* profit; 1911-12, 2111*l.* profit; 1912-13, 1582*l.* loss; 1913-14, 1111*l.* profit; 1914-15, 27,593*l.* profit. The dividends paid for the same years were:—1908-9, 8 per cent.; 1909-10, 6 per cent.; 1910-11, 5 per cent.; 1911-12, 2½ per cent.; 1912-13 and 1913-14, *nil*; and 1914-15, 12½ per cent. Owing to underground difficulties and labour troubles the company had three very lean years; but in 1914-15 it not only distributed a dividend of 12½ per cent., but it also paid off a bank loan of 15,000*l.*, placed 15,000*l.* to reserve, and carried forward 9939*l.* Freight rates have been still going up at Cardiff, new records having been established for Mediterranean ports (Genoa and Marseilles). The Genoa rates reached 77s. 6d. per ton, making an advance of 11s. 6d. per ton since December. The directors of the Gloucester Railway Carriage and Wagon Company, Limited, recommend an interim dividend for the half-year ended November 30 at the rate of 10 per cent. per annum. It is freely predicted at Cardiff that freight rates for Marseilles will reach 4*l.* per ton. British shipowners are not doing so well out of the present extraordinary state of things as neutrals, particularly Greeks, Scandinavians, Americans, and Spaniards; this is due to the fact that British owners have about half their tonnage engaged on Government work, while they have to face all increased costs as well as greatly increased income tax.

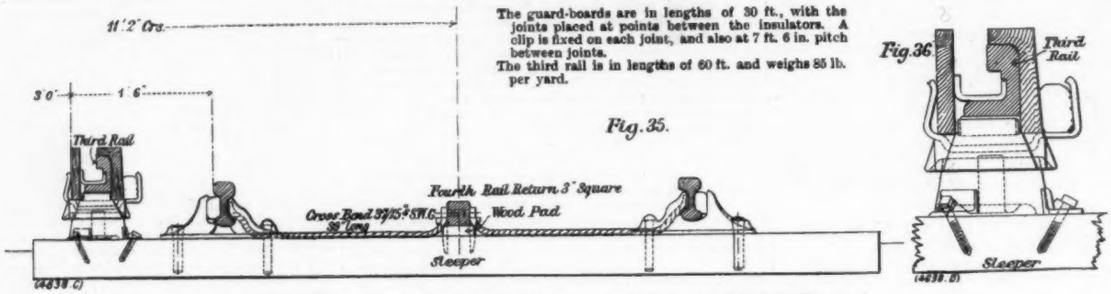
MINING MACHINERY.—The value of the mining machinery exported from the United Kingdom last year was 571,600*l.*, as compared with 819,486*l.* in 1914 and 1,018,150*l.* in 1913. The decrease observable, which was, no doubt, occasioned by the war, was still continuing at the close of last year, the value of the shipments for December having been 42,854*l.*, as compared with 48,800*l.* in December, 1914, and 59,975*l.* in December, 1913. The largest consignments were made last year to South Africa, which took mining machinery in 1915 to the value of 255,204*l.*, as compared with 284,357*l.* and 419,591*l.* The value of the mining machinery exported in each of the ten years ending with 1915 inclusive was:—

Year.	Value.	Year.	Value.
	£		£
1906	733,862	1911	1,034,503
1907	875,151	1912	999,201
1908	912,786	1913	1,018,150
1909	958,226	1914	819,486
1910	1,280,660	1915	571,600

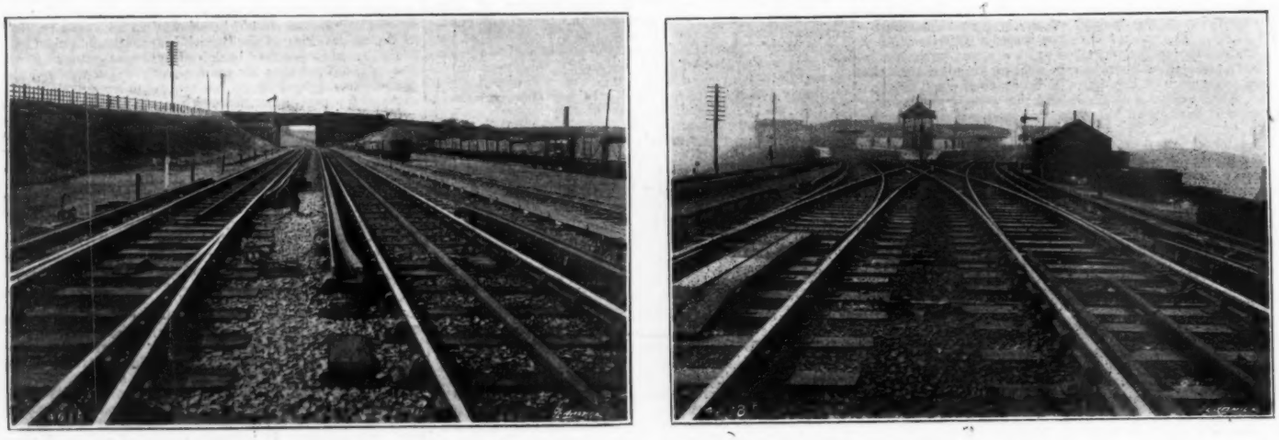
INDIAN RAILWAY ADMINISTRATION.—At the close of March, 1915, the Bengal Nagpur Railway Company had expended 27,640,794*l.* upon its undertaking. The capital expended in 1914-15 was mainly paid out for additional rolling-stock and improvements to the main line and workshops at Kharagpur. At the close of the financial year, 49½ miles of 5-ft. 6-in. gauge and 2½ miles of 2-ft. 6-in. gauge were under construction. The 49½ miles of 5-ft. 6-in. gauge included a second section of the Bokhara and Ramgarh extension, and also the Parvatipuram and Singapur road section of the Raipur and Vizianagram extension, work on which was suspended by order of the Indian Railway Board. The 2½ miles of 2-ft. 6-in. gauge are a short section of the Gondia and Chanda line at Chanda. The average length of line worked in 1914-15 was:—Lines of 5 ft. 6-in. gauge, 1878½ miles; lines of 2-ft. 6-in. gauge, 796 miles; or, altogether, 2674½ miles. The ratio of the working expenses to the traffic receipts in 1914-15 was 50.32 per cent., as compared with 48.51 per cent. in 1913-14, and 45.57 per cent. in 1912-13. The total goods traffic, including coal, was 7,285,123 tons in 1914-15, 7,259,398 tons in 1913-14, and 6,639,354 tons in 1912-13. There was a large increase last year in the revenue derived from the carriage of coal; this was due to increased long-distance coal traffic *via* Nagpur.

ELECTRIFICATION OF THE MANCHESTER TO BURY SECTION; L. AND Y. RAILWAY.

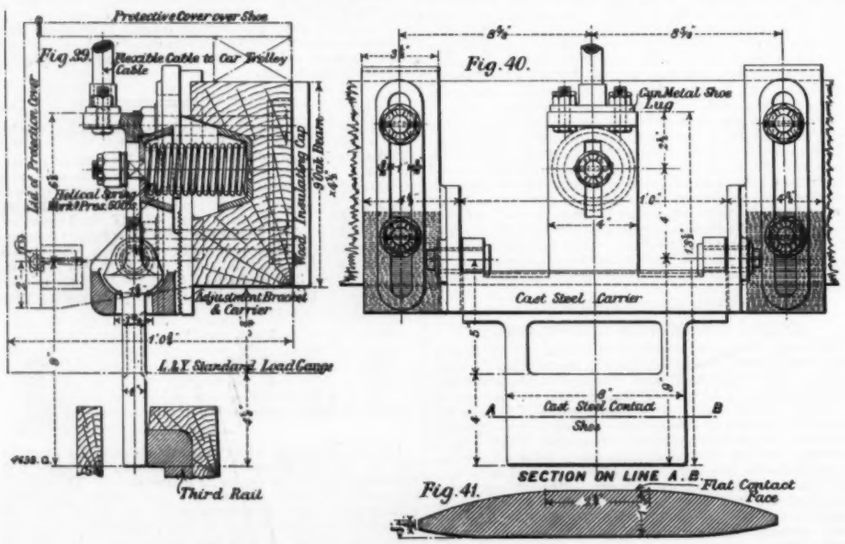
(*For Description, see Page* 55.)


11'2" Crs.
3'0"
1'6"
Third Rail
Fourth Rail Return 3" Square
Wood Pad
Sleeper
The guard-boards are in lengths of 30 ft., with the joints placed at points between the insulators. A clip is fixed on each joint, and also at 7 ft. 6 in. pitch between joints.
The third rail is in lengths of 60 ft. and weighs 85 lb. per yard.
Fig. 35.
Fig. 36.
Third Rail
Sleeper

FIGS. 35 AND 36. PERMANENT WAY WITH THIRD AND FOURTH RAILS.



FIGS. 37 AND 38. VIEWS SHOWING LIVE RAIL AND FOURTH RAIL IN RELATION TO TRACK.



FIGS. 39 TO 41. CONTACT-SHOE AND CONNECTIONS.

MACHINERY IN JAPAN.—Machinery was imported into Japan in 1914 to the value of 2,546,200*l.*, as compared with 3,752,700*l* in 1913, and 2,987,600*l.* in 1912. The share of the United Kingdom in the trade of 1914 was 1,354,500*l.*, as compared with 1,737,800*l.* in 1913, and 1,456,300*l.* in 1912; that of the United States, 505,700*l.*, 754,300*l.*, and 705,600*l.*; that of Germany, 556,100*l.*, 873,600*l.*, and 658,900*l.*; that of France, 25,000*l.*, 24,700*l.*, and 18,500*l.*; and that of other countries, 104,900*l.*, 362,300*l.*, and 148,300*l.* The principal imports were:—Spinning machinery, 544,300*l.*; dynamos, electric motors, transformers, converters, and armatures, 245,800*l.*; metal or wood-working machinery, 253,200*l.*; steam-boilers and accessories, 87,900*l*; locomotives and tenders, 45,700*l.*; gas-engines, 37,300*l.*; pumps, 67,900*l.*; cranes, 34,100*l.*; water turbines and Pelton wheels, 32,800*l.*; weaving-looms, 74,100*l.*; and dynamos combined with motive machinery, 44,500*l.* The Japanese Government Railways have their own inspectors abroad, and upon presentation of their certificates of inspection, payment is made on delivery of goods after further inspection on their arrival in Japan, chiefly with regard to measurements. With Admiralty and War Office orders payable to the value of 25,000*l.*, inspection is made within 15 days of delivery. With larger orders, such as material for warships, payment is spread over the course of construction, running into five or ten amounts. The Admiralty generally places its important orders through inspectors in London, but negotiations are carried on through agents in Japan. In such cases payment is made free on board at British ports, and freight is arranged by the naval inspectors with the Japanese steamship companies.

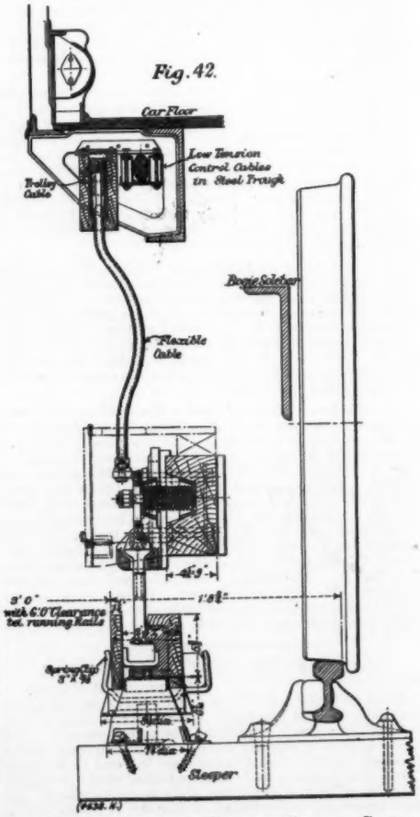


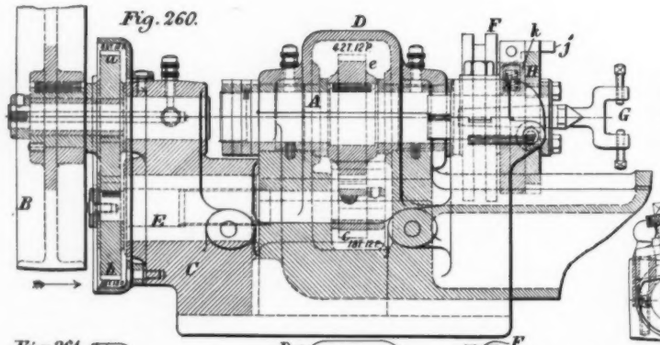
FIG. 42. CONNECTIONS OF SHOE TO TROLLEY-CABLE.

CAM-GRINDING ATTACHMENTS AND

CONSTRUCTED BY THE CHURCHILL MACHINE TOOL CO

(For Description, see P

Fig. 260.



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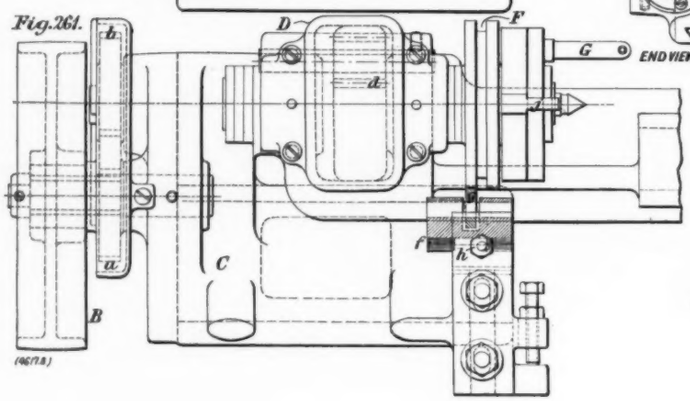

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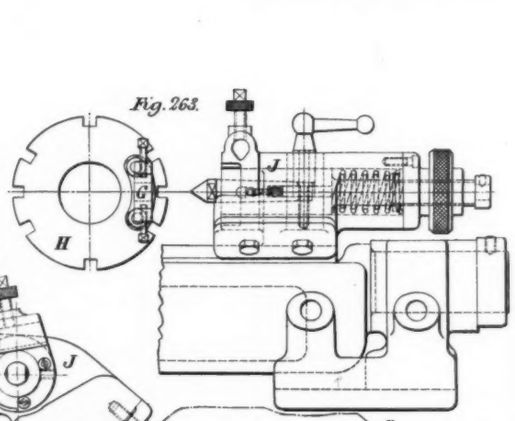

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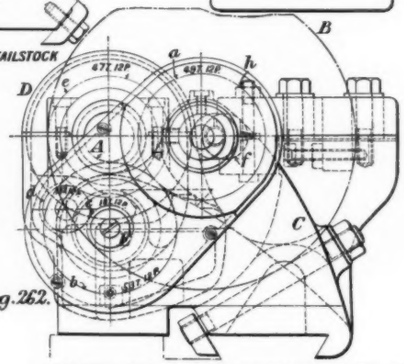
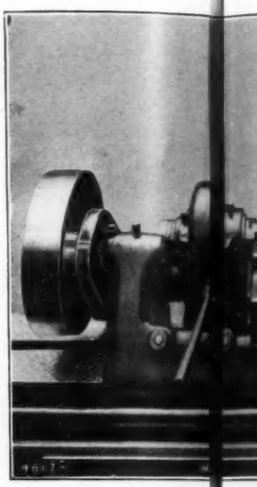


END VIEW LOOKING IN DIRECTION OF ARROW. (Fig. 260)



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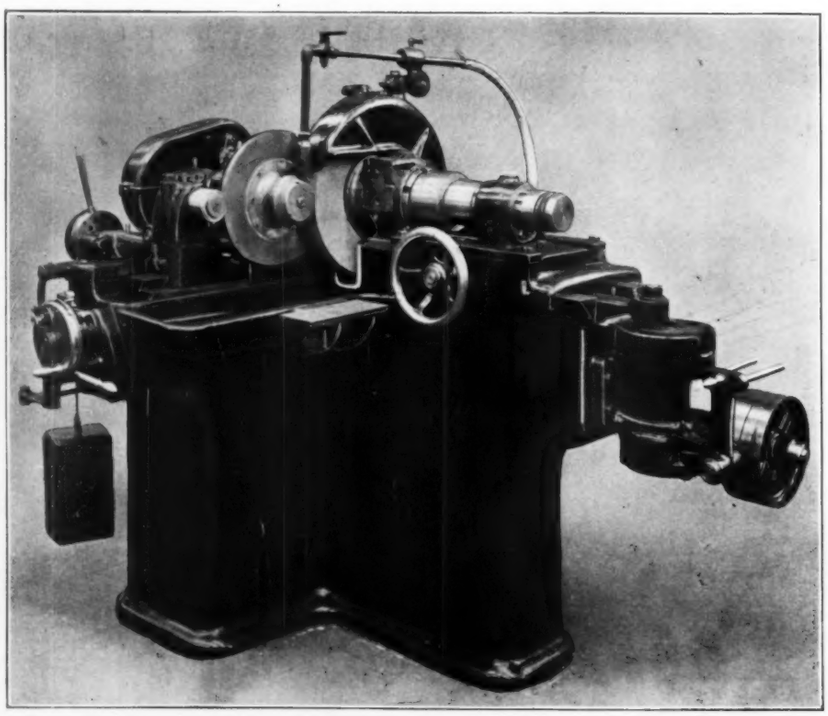
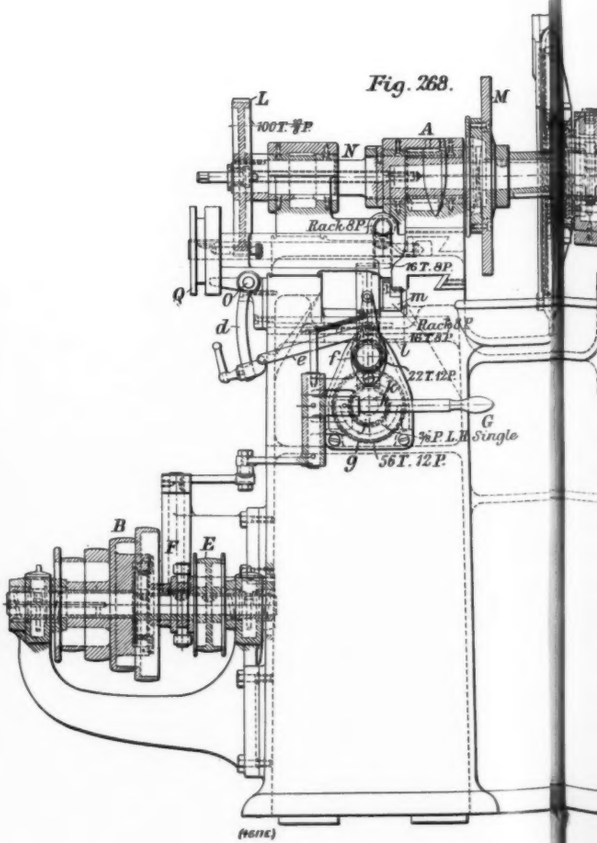


FIG. 267. 16-IN. CAM-GRINDING MACHINE.

Fig. 268.



S AD 16-IN. CAM-GRINDING MACHINE.

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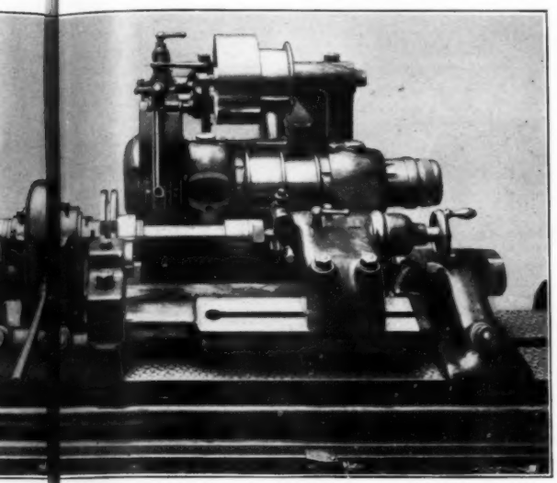
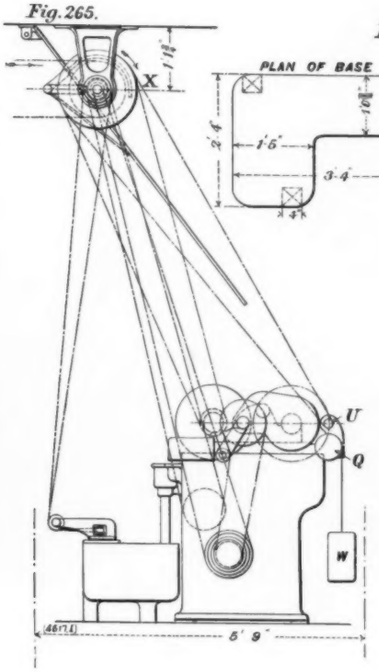


264. CAM-GRINDING ATTACHMENT.

Fig. 265.



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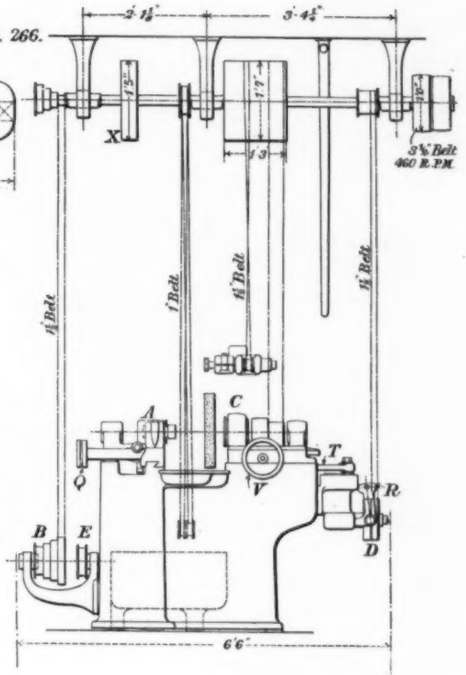


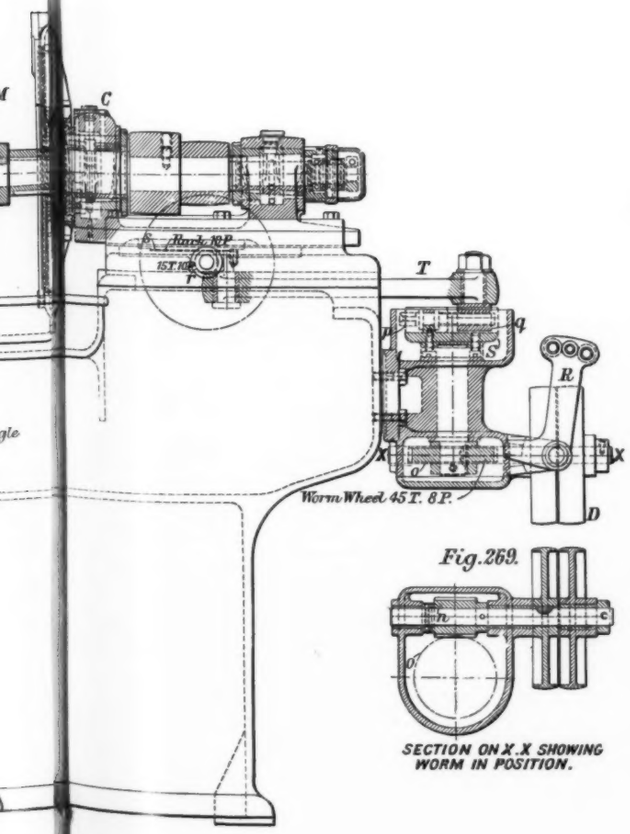


Fig. 269.

SECTION ON X.X SHOWING WORM IN POSITION.

Fig. 270.

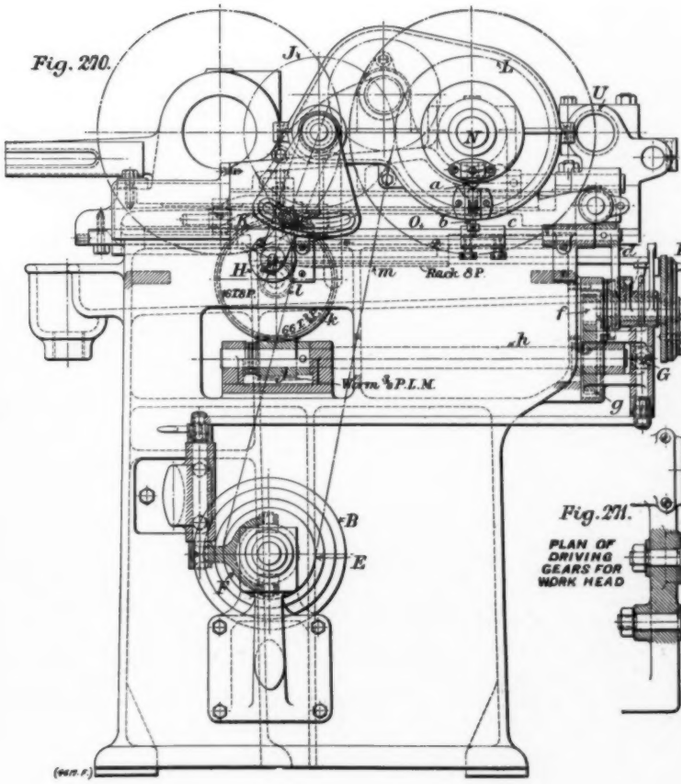
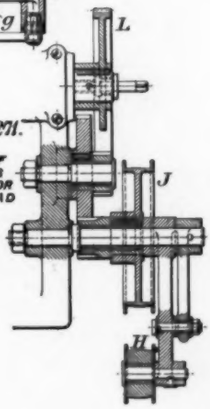


Fig. 271.

PLAN OF DRIVING GEARS FOR WORK HEAD



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NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 21, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. A paper will be read on "The Flow of Air through Nozzles," by Captain Thomas B. Morley, B.Sc. (of the University of Glasgow), Associate Member.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—Saturday, January 22, at the Danum Hotel, Doncaster, at 3.30 p.m. The President (Mr. C. Chetwynd Ellison) will deliver his presidential address. A paper by Mr. E. Lloyd, on "Notes on the Uses and Markets for Coke Oven By-Products."

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 25, at 5.30 p.m. The discussion on the following paper will be continued: "The Electric Locomotive," by Mr. Frederick William Carter, M.A., Assoc. M. Inst. C.E.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, January 26, at 8 p.m., at the Royal Institution, Colquitt-street, when a paper will be read by Mr. G. C. Marris, B.Sc., A.M.I.E.E., entitled "Recent Developments in Telephony."

THE ROYAL SOCIETY OF ARTS.—Wednesday, January 26. "The Effect of the War on Cotton-Growing in the British Empire," by Mr. J. Arthur Hutton, Chairman of the British Cotton-Growing Association. Sir Daniel Morris, K.C.M.G., M.A., D.C.L., D.Sc., F.L.S., will preside. The chair will be taken at 4.30 p.m.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, January 28, at 5.30 p.m., the discourse will be delivered by Dr. Leonard Hill. The subject is "The Science of Clothing and the Prevention of Trench Feet." Afternoon lectures next week at 3 o'clock. Tuesday, January 25, on "The Physiology of Anger and Fear," by Professor Charles S. Sherrington, M.D., LL.D., D.Sc., F.R.S., Fullerian Professor of Physiology, R.I. (Lecture II.). Thursday, January 27, on "The Utilisation of Energy from Coal: Fuel Economy from a National Standpoint," by Professor W. A. Bone, D.Sc., Ph.D., F.R.S. (Lecture II.). Saturday, January 29, on "Raphael and Michelangelo," by Mr. Charles J. Holmes, M.A., Director, National Portrait Gallery (Lecture II.).

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, January 28, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne. The discussion will be resumed on "The Time Element and Related Matters in Some Ship Calculations," by Professor J. J. Welch, M.Sc., Member of Council. The following paper will be read and, time permitting, discussed:—"The Standardisation of Stability Curves," by Mr. Wilfrid Ayre, Associate Member.

THE PHYSICAL SOCIETY OF LONDON.—Friday, January 28, at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W., at 5 p.m.—The second Guthrie Lecture will be delivered by Mr. W. B. Hardy, Sec. R.S. Title: "Some Problems of Living Matter."

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—Saturday, January 29, at Caxton Hall, Westminster, at 3 p.m. Annual general meeting. After the formal business, the President-Elect, Mr. R. E. L. Maunsell, M.A., M.I. Mech. E., Chief Mechanical Engineer of the S.E. and C. Railway, will address the meeting.

THE ASSOCIATION OF MINING ELECTRICAL ENGINEERS: NOTTS AND DERBYSHIRE BRANCH.—Saturday, January 29, at the University College, Nottingham, at 3.30 p.m. Papers for discussion:—"Unusual Breakdowns in Colliery Electrical Plant," by Mr. Roger Devine (East Scotland Branch): "Notes on Experiments with Battery-Signalling Bells, following the Senghenydd Explosion," by G. M. Harvey (Lancashire Branch).

ENGINEERING.

FRIDAY, JANUARY 21, 1916.

LONDON TRAFFIC.

ADVOCATES of municipal speculation in trading ventures frequently make the point that a public authority can in general raise the capital necessary for the undertaking at a lower rate than it is possible for private parties to do, and gain thus an advantage which more or less offsets the lower standard of efficiency commonly characteristic of services owned and operated by the community. Whilst it cannot be denied that public credit stands higher than that of all but exceptional private enterprises, it has notwithstanding to be borne in mind that if the venture proves a failure, the community has nevertheless to continue its payments; whilst had the enterprise been left to the private speculator, the whole of the loss would have fallen on the latter. As a matter of fact, a comparison of actual results shows that in very many cases the community is paying distinctly less for the use of privately controlled capital than it would have had to pay had the speculations in question been undertaken by a public authority. For example, the return on the 66 millions of ordinary capital invested in the urban railways of London is but 2 per cent., a rate much below that at which even such a body as the London County Council could, even in pre-war days, have raised the capital required. There is, moreover, reason to believe that, on the whole, the community is paying no more for the use of the company-owned tramways than it is for the municipal undertakings. Exact figures are, however, difficult to get, since unsuccessful private companies commonly write off large proportions of their capital, making the apparent return on the remainder higher than the true average dividend on the total investment. On the other hand, the amounts annually attributed to interest on municipal loans do not give a clear indication of the rate at which the capital was originally raised.

In the provinces, of course, the public ownership and management of transport facilities has been accompanied by a stolid opposition to the introduction of improved methods of transportation in the fear that these might seriously affect the tramway receipts. No doubt this danger is far from illusory, but at the same time experience has shown that the larger proportion of the passengers patronising the motor-bus is obtained by the tapping of new sources. This was particularly well shown by Sir Albert Stanley in a paper read before the Engineering Congress at San Francisco last September. In this paper Sir Albert gave a most instructive and detailed description of London traffic as it exists to-day.

In the year 1911 the number of passengers carried by the London County Council Tramways was 516 million, which at that date represented 60 per cent. of the total tram and omnibus traffic. In 1913 this total had increased to 523 million, but at the same time the omnibus traffic had risen from 340 million in 1911 to 705 million, so that the proportion of the whole secured by the trams had fallen to 41.8 per cent., whilst that of the omnibuses had risen to 58.2 per cent. In the first half of 1914, again, the omnibuses carried 388 million passengers, corresponding, say, to nearly 800 million per annum had pre-war conditions continued. In 1911 the omnibuses carried 340 million, so that in the course of two years the traffic had more than doubled. Only the most reckless of politicians would venture to assert that the tramways could have secured more than a very small fraction of this increase had they been protected against competition, as they are in Glasgow, Manchester, and other provincial towns. The figures indeed demonstrate in a most striking way how large must be the indirect loss suffered by these communities through their policy of establishing a monopoly in transport facilities.

The causes of the great popularity of the motor-bus are very clearly set forth in Sir Albert's paper. He states that in no case do the omnibuses merely parallel the tramways. Even where they traverse the same streets for long distances, they extend into areas otherwise untouched. In fact, the diversity of service offered would be impracticable with any system of tramways commercially possible. For example, the omnibuses traversing the section between Oxford Circus and Bond-street belong to no less than fourteen distinct services. By no practical expenditure would it be possible to give an equal service by means of tramways. The new traffic created by the omnibuses is, however, not attributable to this circumstance only, but to the greater efficiency of the services offered even along routes provided with tramways. This greater efficiency of service is, it is of interest to note, acknowledged as the determining factor in the success of the "Jitney" omnibus in America. In a paper published recently in *The General Electric Review*, Mr. J. C. Thirlwell advanced the opinion that the only course open to the tramway companies in the United States was to endeavour to give an equal service by reducing the size and increasing the frequency of their cars; indeed, he proposed the adoption of cars seating 32 only. It is interesting to compare this conclusion of the practical man with that which commended itself to the politicians of the London County Council, who seriously contended before the late Royal Commission that the larger the car the better and more efficient the service. As matters stand, the average seating capacity of the London County Council tramcars is 74, and the average number of passengers carried is 10½. The number of cars in service is 2780, and these take, as stated, 522 million passengers per annum. The mileage of line traversed is 145, and the cost some 12½ millions sterling. The motor-buses, on the other hand, have a seating capacity of 34, and their average load is eight passengers. In the week-day service these omnibuses traverse 551 miles of road and 127 different routes. The number of omnibuses owned is 3525, of which no less than 3477 were in service on Whit Monday, 1914, a figure which bears eloquent testimony to the reliability of the vehicle as at present constructed.

In this connection it should be remembered that all the easier lines for the establishment of tramways are already taken up, and that extensions to the existing system will by no means secure traffic in proportion to the additional expenditure.

Sir Albert Stanley states that with roads having a proper foundation the motor-bus causes less injury than horsed traffic, and this contention is borne

out by the report of the Metropolitan Committee on Materials and Means of Paving the London Streets, issued in January, 1913. In this report the surveyors of districts having streets with good foundations stated that, if anything, the cost of road maintenance had been decreased by the advent of the motor-bus. Of course, in other cases the damage done has been serious; and it has been suggested that a special tax should be levied on the traffic accordingly. The fairest way to do this would, no doubt, be to ear-mark for road repairs and reconstruction the large sums now paid by the omnibus companies in the shape of petrol-tax. This, according to a Board of Trade report, is equivalent to 0.008d. per seat-mile, whilst the cost to the tramways of the road maintenance for which they are responsible is stated to be 0.007d. per seat-mile. As matters stand, however, the contributions made by the omnibus companies to road maintenance are for the main part not available for road repair and reconstruction in the Metropolitan area.

The average fare per passenger carried is 1.33d. on the omnibuses and 1.01d. on the London County Council tramways, the corresponding expenses being 0.94d. and 0.75d. respectively. The average distance covered by a penny fare is 1.7 miles on the omnibuses, and increases uniformly with the distance, the average length of a 3d. stage being 5.1 miles. On the London electric railways, on the other hand, the fare is proportionately less the greater the distance. This has long been recognised as the most logical method of fixing railway fares, since the terminal charges per passenger are much the same whatever the distance traversed, and they moreover constitute a substantial proportion of the total cost. For various reasons—of which one lies in the fear of trouble to be anticipated from passengers booking to distant points, but alighting at an intermediate one, and selling the remainder of their ticket—this system has not been adopted by main-line railways. On the London electric lines such considerations hardly apply, and the fares are graduated accordingly. Thus the average 1d. fare stage is 1.4 miles, whilst the 3d. stage is 5.1 miles. Possibly a still greater graduation than this would be adopted were it not for the fact that surface competition is very serious in the case of the shorter stages, but diminishes in intensity as the distance increases. The two elements which determine travel are the cost and the time taken. The importance of the latter factor was much under-estimated in past years. In the London area Sir Albert Stanley states that experience shows that 4d. is about the fare limit, season tickets being preferred if the ordinary fare is greater than the figure stated. The time limit is about 40 minutes.

It is noteworthy that the travelling habit in the London area appears to be less developed than in New York, with 338 trips per head per annum, and in Berlin with 293. The corresponding figure for London is 271, but it is not certain that the basis of calculation is the same in all three cases. The London figure is that corresponding to the Greater London area, including the Outer Suburban Districts, with a population of 8,470,000, and an area, according to Sir Albert Stanley, of about 2800 square miles. The density, therefore, is only 2.1 to the acre. If the average density is greater for the New York and Berlin areas, the higher travel rate in these two cities would be accounted for. As is well known, the density of population in the inner area of Berlin is more than double the corresponding figure for London. In fact, the average for Berlin — viz., 130 per acre—is not much less than the 170 per acre of Shoreditch, Bethnal Green, and Southwark, which are the most densely populated portions of our Metropolis. The consequent overcrowding in Berlin has raised land values there to three times that of corresponding areas in London. It is, nevertheless, to an improvement in the travel habit that Sir Albert Stanley looks for securing a fair return on the capital expended on our urban railways. The Tubes have, he says, cost 785,000*l.* per mile, and parts of the District and Metropolitan lines as much as a million a mile. The average fare per passenger on the Tubes is 1.68d., and on the District Railway 1.83d. It requires an enormous number of such fares to provide a reasonable return on such heavy investments as the foregoing. Another thirty journeys per head per annum would, however, enable the dividend to be raised to 4 per cent.

With insignificant exceptions, the whole of the motor-bus undertakings of the Metropolis have been consolidated into a pool, there being but eighteen omnibuses outside of the combination. It is, however, open to any one to start new services, since the police are bound to license any vehicle conforming to their requirements. Sir Albert Stanley states that small independent companies confine their attention to the short central sections of very dense traffic, leaving the longer services, some of which are still unremunerative, to be maintained solely by the consolidated companies. Evidently he would prefer to work under a franchise, by which competition of this kind would be restricted; and in return would be prepared to give special cheap workmen's services and to submit to a limitation of fares. The controlling authority, however, he very justly observes, must not be itself a competitor, so the London County Council is ineligible, but a traffic control board, such as was suggested in 1907, would be accepted.

In our view it is very doubtful whether an arrangement of the kind proposed would be to the ultimate advantage of the public To assume that the final word has already been said on matters of urban transport would be exceedingly rash, though it may be quite true that there is at present no apparent prospect of any important innovation in existing methods. The history of the motor-bus development is, however, in itself a warning against any such hypothesis of finality. The very Commission which advised the establishment of a traffic board made other recommendations, based on a similar assumption to the foregoing, which were obsolete within a few months of their publication. Like others, they utterly failed to anticipate the extraordinary development of the motor-bus. Further, it has to be noted that the pioneering work leading to this development was undertaken not by the great and wealthy London General Omnibus Company, but by small independent companies, who, in fact, forced the hands of their old-established rival. Large bodies are notoriously inert, and the grant of a monopoly such as suggested by Sir Albert Stanley would, in all probability, seriously handicap future progress.

A peculiarity of the omnibus traffic is the absence of any very accentuated peak in its daily load. On a typical route the maximum load occurs at about 8 o'clock in the morning, and amounts to 7500 passengers per hour, the mean for the whole day being about 4900. On the electric railways, on the other hand, there are three well-marked peaks. The greatest of these is also at 8 A.M., at which hour the passenger traffic amounts to 49,000 per hour; a second, but lower, maximum of 23,500 per hour is experienced at 7 P.M., and a third maximum of 13,000 per hour at 12 P.M. The mean figure for the working day, from 6 A.M. to 1 A.M. on the following morning, is 14,000, so that the maximum is about 3½ times the mean.

Very heavy expenditure and much hard thinking have been necessary to enable the railways to cope with the enormous peaks in question. In the old days of steam traction but 18 trains each way per hour could be run over the District lines between the Mansion House and South Kensington. With electric traction and the simultaneous adoption of automatic signalling, rendering shorter blocks feasible, this figure was raised to 25 trains each way per hour. The next step taken was to smarten up the station staffs, so as to get the trains away more quickly, with the result that at the close of 1907 the number each way per hour was raised to 31. In 1908, by rearranging the services over the different branches at the West End, so as to avoid clashing, a further increase to 35 trains per hour was effected.

Further study showed that an alteration in the platform arrangements at the Mansion House would effect a material saving of time there, and by making these changes, with some modifications in the signalling arrangements, reducing the permissible headway between trains, the number of services was raised in 1911 to 37 in each direction per hour. Work was next started in constructing fly-over junctions between the main line and the various branch lines at the West End, and as a result the number of trains per hour in each direction was raised to 43 in 1914. On the completion of schemes now in contemplation this figure will, it is anticipated, be raised to 50 per hour each way. Even so, however, it is not expected that overcrowding will be eliminated during periods of maximum loads. It is probably quite impossible to effect this on any urban railway service, since the greater the facilities offered the more rapidly the traffic appears to grow.

OIL STORAGE.

IN many parts of the world petroleum tanks and grain elevators, in their hideous massiveness, form eyesores hopelessly disfiguring picturesque shores and pretty landscapes. The war may deliver us from this evil. We do not expect the improvement indicated because warriors are troubled by æsthetic considerations. But petroleum tanks and grain-elevators are not only unpleasantly, but also dangerously conspicuous, and for that reason they will probably be anathematised. How petroleum tanks became what they are, and how oil storage might be modified, was explained by Mr. Herbert Barringer, M. Inst. C.E., &c., in a paper read before the Institute of Petroleum Technologists last Tuesday in the lecture theatre of the Royal Society of Arts.

The finding of oil necessitates some form of storage in close proximity to the well. In the early days rough holes of large capacity were dug in the ground, more or less cylindrical or rectangular, the sides being lined with clay or wood, and a roof being made of thin iron plates supported on wooden rafters, or altogether of wood covered with asphalted felting. Mr. Barringer showed photographs of reservoirs of the latter type, still common in Galicia. Wooden tanks, resembling huge vats, are used to a considerable extent in America. But iron and steel are now the common materials. In this country oil arrived first in barrels, which were emptied into underground tanks, from which the oil was again drawn into barrels for distribution; the wharves of Mellish and Palmer, Mr. Barringer thought, were first so adapted over here in 1868. The advent of steamship bulk-oil carriers, however, had called for provision of storage installations all over the world, and Mr. Barringer dealt with the actual problems of oil storage under four headings.

Dealing first with general principles, he pointed out that many factors had carefully to be considered in selecting a site: water frontage, communication by rail, &c., fire danger from the surrounding neighbourhood, restrictions by local authorities, and the nature of the ground. There should be ample area at disposal; the position of the tanks should not interfere with future operations; the tanks should be surrounded by a bank or wall of concrete sufficiently high, so that the cubic space enclosed should not be less than 5 per cent. above the total capacity of the tankage within; that was, perhaps, an unnecessarily harsh regulation, he thought. As a tank of 90-ft. diameter would float, empty, in 12 in. of water, good drainage of the site was essential, lest the floating tank should break the pipe-connection and valves. Standards with swing-pipes or hose were required along railway sidings and roadways, the standards to be charged with oil by gravitation or pumping; if more than one kind of oil were to be dealt with, separate pipe-lines should be provided. Steam-boilers were wanted, even with electric power installations, for preparing the barrels, heating the oil, and when discharging spirit. The danger from boiler-fires could be minimised; the boiler-house, of brick or concrete, should be on a higher level, and entrance to it be barred by a coaming at least 3 ft. 6 in. in height, to keep oil-vapours (heavier than air) from the fires. Electric lighting was alone to be tolerated, of course, and the power and boiler-houses should be near the landing-stage, and as far away from the tanks as possible.

Passing to the foundation and construction of tanks, Mr. Barringer remarked that the weight-bearing capacity of the soil should be carefully determined in the first instance, by weighting or by sinking pits, and the soil should be then removed so as to allow the creation of a bed of clean ballast or sand, about 10 in. above the level of the surrounding ground, slightly higher (by 4 in. to 7 in.) in the centre than at the circumference, and some 6 ft. wider than the diameter of the tank. The tank might be placed on a raft of heavy baulks of ample dimensions; piling might be unavoidable; reinforced concrete was used; solid concrete had better be avoided, as it weighted the foundations and was apt to break up. Brushwood and faggots might answer to reinforce the ground. A tank had

also been placed in some cases on a large steel disc, a layer of tarred wood, ¾ in. thick, being interposed between the tank bottom and the disc; wood or sand were likewise interposed when a tank rested on hard rock.

The tanks were now almost universally cylindrical, up to 100 ft. in diameter and 30 ft. to 37 ft. in height. A tank of 90 ft. diameter, 35½ ft. high—a very usual size—would hold 1,337,640 gallons. The bottom of the tank should not be less than ⅜ in. thick; to save on that thickness meant stronger foundations, and a questionable saving. The sides were built in a series of rings or strakes of plating; the attachment of the bottom to the strakes was made by an angle bar, double riveted, like the vertical side seams (which might also be treble riveted), whilst the bottom plates were single riveted. In order to facilitate the renewal of the bottom plating in cases of acid corrosion, without lifting the entire structure, the lowest strake of the side plating was, in a novel construction, attached to the annular bottom plating in the ordinary way, but the main bottom of the tank was raised and riveted to the upper flange of a Z-bar, the lower flange of which was attached to the inner circumference of the annular plate; the gutter-way all round the tank could be cemented. This design was somewhat expensive, and was subsequently criticised by Mr. Anfilligoff. Mr. Barringer did not recommend providing a pocket or well in the bottom, supplied with a pipe for draining off any water. The roof should be domed or conical, the rafters being riveted to a stout centre plate, or it should consist of a braced structure. In the erection of tanks the bottom and lower strakes were usually riveted while supported on blocks or on empty barrels, the seams were caulked on both sides, after the water had been run off, and the bottom examined for leaks from below; the bottom was then lowered on to the bed, large tanks being braced during this operation. Walking on the slippery roof being dangerous, stanchions and hand-rails should be provided all round, Mr. Barringer continued, and hand-rails should also lead from the centre of the top to each of the four manholes. These stanchions and hand-rails could serve as lightning-conductors, but the tank should be well earthed. Gauge-glasses on the outside were not reliable, particularly when exposed to the sun, also because the tanks were frequently out of plumb.

Coming to testing and other details, Mr. Barringer recommended leaving painting (outside) until the mill-scale had been removed by rusting. Heavy, viscous oils required to be heated by water or steam-pipes. Tanks for petroleum spirit were sometimes made air-tight and joined to a condenser, from which the spirit distilled over was pumped back; in temperate climates, however, the results hardly justified the expenditure involved. Nor were water-cooled roofs, introduced together with many other features from America, of much utility; to support the roof by a central pillar was of questionable advantage. To build tanks into rock excavations, as was done by one firm in the Midlands, did not seem advisable either. The accurate determination of the capacity of a tank was very necessary and required many steel-tape measurements. The amount of water present was estimated with the aid of apparatus, consisting of a sinker-weight carrying a strip of chemically-prepared paper, which was lowered in several positions; in the case of viscous oils, pointed weights should be used. Convenient apparatus of this kind have been introduced by Mr. Robert Redwood, who showed them at the end of the lecture; his paper is coloured red with ferric citrate of ammonium, which turns white in the water.

As regards machinery, Mr. Barringer stated it was good practice to fit an internal swing-pipe inside the tank, working in a packed socket, with a flange connected to the side of the tank through a distance-piece to a valve fitted outside the tank; the inner end of the pipe could then be raised or lowered with the aid of a worm-driven winch and a wire passing over the outer edge of the tank, and oil could be withdrawn from any level in the tank. The end of the swing-pipe was fitted with a flexible metallic tube and a heating coil. Internal drop-valves were apt to give trouble, and inlet piping, carried up to the top of the tank outside and then down inside to the bottom, required another inconvenient connection for drawing off, to be fitted at the lower part of the tank. The connections between piping and tank were liable to strain the piping, as the ground under the tank was frequently overloaded. The strain could be avoided in several ways: by the use of elbows so designed that movement was taken up at the screwed joints; by a yielding coil construction dispensing with joints; by copper connecting-bends, which were expensive, however; and by flexible hose. The main delivery-pipe should be of ample diameter, and might well consist of several pipes. Viscous oils had to be heated while flowing through the pipe; that might be done by the aid of an internal steam-pipe, which might break or leak, however. It was better, therefore, to run one or several steam-pipes outside the pipe-line, clipped to the lower side and covered with a sheet-iron guard, carried half-way round and lagged. Long pipe-lines exposed to the sun required relief-valves. All pipes should be kept above ground so far as possible, and rest on cement blocks, but not be fixed to them; expansion loop joints were preferable to packed expansion-sockets, though not sufficient for hot oil flow. The pipe material should be mild steel, lap-welded, without flanges, especially where different oils were to be dealt with; the line to the ship should be emptied with the aid of an air-pump and receiver before taking in new oil.

As regards pumps, Mr. Barringer advocated pumps with by-pass, easy to reverse, of the direct-acting duplex or simplex types, or three-throw geared pumps if driven by electric motors or internal-combustion engines; he had no objection, however, to high-lift centrifugal pumps, which Mr. Dally afterwards recommended. The generally favoured valve was the full-passage through-way-gate valve, brass-faced. Filters were made of wire gauze, in duplicate frequently, so that they might alternately be cleaned; they should be of ample area. Compressed paper, red fibre and litharge formed the best materials for flange joints. With respect to fire protection, Mr. Barringer mentioned the froth mixtures (soda aluminium sulphate, and liquorice, or some other organic compound) which we have noticed; but he did not speak of personal experience. As a rule it was safe to let a tank fire burn itself out.

Mr. Barringer's remarks under his fourth heading, on existing installations, were curtailed by the political situation. Rapid delivery called for lines of exceptional size, and that was now an important feature, especially in Admiralty work, with which he was closely associated. He referred in particular to the storage of petrol. The petrol, so largely wanted now both in town and country, could be stored underground and the tanks be covered with concrete; all the spirit would have to be pumped, as the canning-sheds were above ground; the pumps should be duplex, compressed-air machines, driven by automatically-controlled electric motors, which would keep the pressure in the air reservoir between 30 lb. and 60 lb. per sq. in.; all petrol piping should be laid in concrete trenches filled with sand and ½ in. of cement, covered by iron chequer-plate; for jointing, red fibre and litharge had again given good results. Lights in the sheds, &c., should be placed outside the windows and fitted with reflectors.

The storage of lubricating oil was less difficult. The oil had to be freed of water, which made the oil cloudy, and this could be done by heating the oil in a special tank and by introducing heated compressed air into the oil; the air-bubbles rising absorbed the moisture, and discharged it as steam.

Mr. Barringer finally drew attention to a novelty—subaqueous storage and also transport of oil—due to Messrs. Doxford, of Sunderland. It was desirable, he said, to keep the location of the stores secret, and, as Sir B. Redwood, the chairman, pointed out, to change the position of the stores occasionally, and, further, to protect the oil from guns and air-craft. That was effected by storing the oil in cylindrical vessels with hemispherical ends, kept under water at the bottom of a harbour. This barge-tank, 150 ft. long, 30 ft. in diameter, would carry 2400 tons of liquid fuel, and could be submerged with the help of ballasting compartments at both ends. From each oil compartment three connections were led to the valve-room—one for ballasting, one for dealing with the oil, and one for admitting or expelling air. To bring the vessel up from the bottom, compressed air was introduced in order to force out about 30 tons of ballast water; sometimes oil or water could simply be pumped out with the help of a flexible hose to make the vessel rise. When the barge was to remain at the bottom, water was allowed partly to replace the pumped-out oil; oil and water then came in contact with one another, but by fitting the sea-valves and pump sections well apart, and by introducing baffle-plates in the way of the pump suctions, any mixing of the two liquids could be avoided. Messrs. Doxford had also designed a cylinder, 450 ft. long, 50 ft. 9 in. mean diameter, capable of containing 20,000 tons of oil at 39 cub. ft. to the ton. This vessel was designed on the Jack-Doxford balanced-pressure system, and was intended to float, moored in the harbour; it would sink more and more as water took the place of the oil discharged, but would remain afloat, a channel in the centre, running the whole length of the vessel, giving the reserve buoyancy; all the valves were operated from this space. By this arrangement all bending moments in the structure were eliminated; it was ballasted with pig-iron and cement.

These submersible barges were also commercially interesting. The barge could be brought alongside a tank steamer or ship when there was no shore accommodation nor time to spare; and, with the increasing use of liquid fuel on board, the need of such ready temporary installations would become generally felt. Messrs. Doxford had, moreover, gone one step further. Mr. Barringer showed a model of a steel barge to be towed across the Atlantic. It represented a long cylindrical body, without keel (though bilge-keels might be added), provided with a short bow and a short stern, to carry 6500 tons of oil at 28½ ft. draught. This vessel could be towed by a ship with the aid of a bridle line; wind and waves would not greatly disturb such a cylinder, which would not require any steering in the open sea, though navigation in closed waters would be difficult. As the barge would always carry its own lights, it would not be a danger to shipping, even if the towing-line should break and the barge drift about.

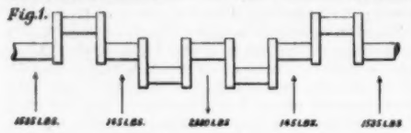
That such transport was not unusually risky was pointed out by Sir Boverton Redwood. The Standard Oil Company had first sent a barge, charged with 6000 tons of gas oil, in tow of the Iroquois, across the Atlantic ten years ago, and had hardly had to interrupt that service since. As regards lightning, Sir Boverton would stretch barbed wires about 2 ft. above the top of the tank, between uprights. The raising and displacement of petrol spirit by the aid of water did no longer offer any difficulty; it was easy to avoid both delivering any water with the spirit and discharging any spirit into the drains together with the water. Mr. Anfilligoff, to whom we have already referred, commented on several other points. He did not like outside elbows, which were liable to rusting, and he certainly preferred heating the oil in the pipe by an internal steam-pipe; if the pipe were solid-drawn, not welded, only 1 in. in diameter, tapering at the ends, and fitted into sockets, no bursting and trouble from expansion need be feared. Straight expansion joints were indispensable for pipes conveying hot oil. He would not dry lubricating oil by forcing hot air through it, especially not Russian oils, which contained alkali, and Texan and American oils, which were far too sensitive and turned black when breathed upon. He also deprecated the use of compressed-air machinery as expensive and likely to cause trouble by giving deposits of ice or of hardened oils in inconvenient places, especially in blended mineral and vegetable oils. Mr. McDougall related how he had converted 40 ft. of liquid mud by embedding stones in it into a suitable foundation. Mr. A. Duckham also made several suggestions; he would replace the iron chequer-plates by wood, to obviate accidental sparking, and had found compressed paper and shellac a good jointing material. The new floating-tanks were undoubtedly the most interesting feature of the discourse; but we are not sure that Mr. Barringer will be able to publish the diagrams which he exhibited.

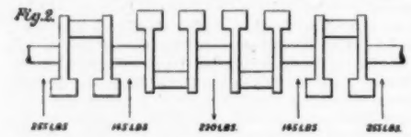
THE BALANCING OF PETROL-MOTORS.

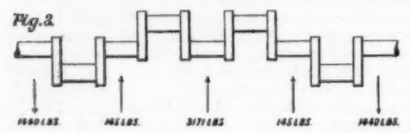
WHEN we study the construction of the ordinary vertical four-cylinder petrol-motor, as used in motor-cars, motor-lorries, motor-boats, &c., it is rather surprising to note how seldom balance-weights are used for the cranks. With the usual disposition of the cranks the engine is balanced as a whole as regards the primary forces, and the addition of balance-weights to the cranks would not therefore affect the vibration of the car. The engine is, however, only balanced as a whole by

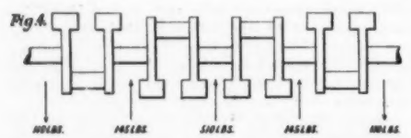
the balancing of one crank by another, and a study of the forces will show that the absence of balance-weights entails very heavy stresses and pressures on the various parts.

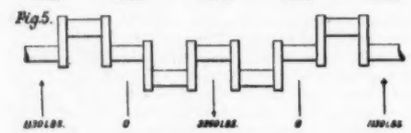
In considering the effect of balance-weights, it must be borne in mind that the greater proportion of both the stresses on the parts and the pressures on the bearings is caused by the inertia forces, especially in the fashionable type of motor-car engine which runs at a very high speed. The ordinary motor-car crank-shaft with five bearings is shown in Fig. 1. As regards the primary force, this is in perfect balance, for the forces acting on the two middle cranks are opposite in direction to the two end ones. If we consider the crank-shaft as divided in the middle into two pairs, each pair has a rocking moment; but as these are in opposite

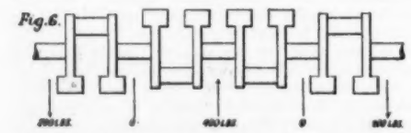










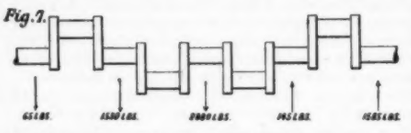


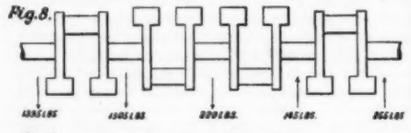
directions, they balance each other. Unless the shaft is made with only two bearings and stiff enough not to spring (which is not usually the case) it must, however, be kept in line by the main bearings, which therefore take the whole of the pressures due to these rocking moments and communicate them to the crank-case. These pressures are due to the various inertia forces and consist of :—1. The inertia forces due to the piston and other reciprocating parts. 2. The centrifugal force of the big end, crank-pin and crank-webs. It is obvious that these can be balanced to the same extent on a motor-car engine as on any other by fitting balance-weights opposite the cranks, as in Fig. 2. It is, of course, impossible in this way perfectly to balance the reciprocating parts, for if the balance-weights balance them perfectly at half stroke they would themselves be unbalanced at the top and bottom of the stroke. For this reason the best compromise that can be effected is usually to balance the whole of the rotating parts and half the reciprocating parts.

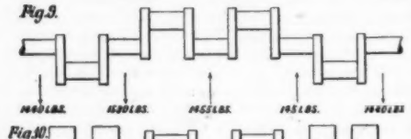
In order to see what is the actual effect of the want of balance-weights, we may take an individual engine as an example, and compare the forces acting on the bearings in an unbalanced shaft and in one with suitable balance-weights. As an example, we may take an engine of modern proportions—say, 95 mm. in diameter, 140 mm. stroke (3¾ in. and 5½ in.), running at 2000 revolutions per minute. Such an engine will have reciprocating parts weighing some 2½ lb., while the rotating parts will weigh about 7 lb.

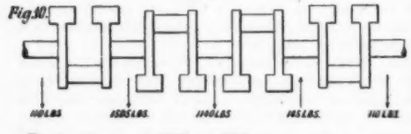
Fig. 1 shows the pressures which will theoretically be produced on the main bearings by the inertia forces of the above weights with the two middle cranks at the bottom of the stroke. It will be seen that they are very considerable, the pressure on each of the end bearings being about 15 cwt., while that on the middle bearing is a good deal over 1 ton. If we balance the crank-shaft by means of balance-weights on the crank-webs, totalling 8½ lb. for each cylinder, we get the pressures shown in Fig. 2, which are obviously very much less, that on the middle bearing being reduced to about one-tenth. Similarly, when the two middle pistons are at the top of the stroke, the pressures on the bearings will be as shown in Fig. 3 with an unbalanced crank, and as in Fig. 4 with a balanced one. Here the pressure on the centre bearing is reduced from 3170 lb. to 510 lb., and on the two end bearings from 1440 lb. to 110 lb.

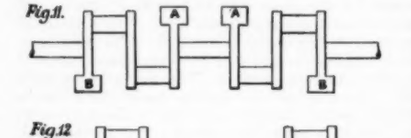
At half stroke the pressures on the bearings are simply those due to the centrifugal forces of the

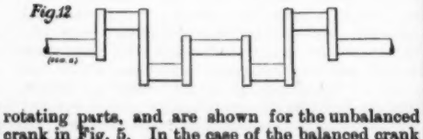












rotating parts, and are shown for the unbalanced crank in Fig. 5. In the case of the balanced crank the pressures on the bearings are due to the fact that the balance-weights are heavier than the rotating parts of the crank-pin, &c., and are therefore partly unbalanced themselves; these are shown in Fig. 6. It will be seen that in the case of the balanced shaft the pressures are less than one-fifth of those of the unbalanced shaft.

In the above calculations no account is taken of the working pressure on the pistons, and the inertia forces alone are considered. In practice the engine would seldom be run at the assumed speed without some explosion pressure in the cylinders. In a motor-car such a condition of affairs might take place if the car were run down hill with the engine in gear.

The explosion pressure will depend largely on how much the throttle is opened. Most modern cars have enough power to do the greater part of their work with the throttle only partially open, in which case the explosion pressure will only be very moderate. Assuming a maximum pressure of 300 lb. per sq. in., the pressure on the unbalanced crank will be as Fig. 7, and of the balanced one as Fig. 8, with No. 1 cylinder firing. Figs. 9 and 10 show the pressures on the unbalanced and balanced cranks when No. 2 cylinder is firing.

In considering the modifying effect of these explosion pressures, it must be remembered that the maximum pressure only occurs at the explosion point, and very rapidly falls, while the pressures on the bearings at half stroke are not materially changed by the explosion pressures. Hence the inertia pressures are much the most important factor in producing wear in the bearings.

In an engine of the three-bearing type the balancing can usually be somewhat simplified. Thus Fig. 11 shows such a shaft balanced as above. It is obvious that the balance-weights A, A, being exactly opposite B, B, the balance is not affected by doing away with both of them, the crank-shaft being then as Fig. 12.

In estimating the above pressures it has been assumed that the bending moments on the shaft are resisted entirely by the bearings. It is obvious, however, that if the shaft were absolutely rigid, the pressures due to inertia would almost balance each other, and the bearings would only be subject to the resultant. In practice the rigidity of the shaft probably has some considerable effect in modifying the pressures due to the unbalanced inertia forces, the amount of this modification depending on the relative rigidity of the crank-shaft to the bearings and the thickness of the oil-film.

It is probably partly to secure more rigidity, and therefore to reduce the pressures on the bearings, that the crank-shafts of modern car motors are made so enormous in proportion to the diameters of the cylinders. It appears, however, that it would be much better practice to balance the crank-shaft properly. In this case the pressure on the bearings and also the stresses on the crank-case could be considerably reduced, and therefore a lighter shaft and crank-case could be used. The wear on the main bearings would be less and the engine could therefore be reduced in length. It would also not be necessary to make the crank-case so rigid, and therefore it could be much lighter.

NOTES.

MELTING-POINTS AND TRANSITION PHENOMENA.

FOR the investigation of the behaviour of potassium salts, Ernst Jänecke, of Hanover, recently devised an electrically-heated press which has proved very convenient for the determination of the melting-points of salts and salt mixtures, and for the study of the transition phenomena of salts, metals, and alloys. Some of the data, published in a series of articles in the *Zeitschrift für Physikalische Chemie*, vol. xc., pages 257 to 339, September, 1915, confirm previous observations; some are quite new and of considerable interest. The substance to be experimented with is compressed in a vertical steel cylinder, 140 mm. long, 30 mm. bore, and 80 mm. external diameter. A plunger enters the upper end of the cylinder, while the lower end is occupied by three fixed perforated cylindrical blocks, one above another, so arranged that liquid can escape through them while solid matter is retained, the substance under test being on the upper of the three cylindrical blocks and below the plunger. Calling the plunger B, and the three blocks respectively C, D, and E, C is provided with an axial bore, 4 mm. in diameter, which opens out near the bottom, so that the cross-section of the bore is an inverted T. When the substance is melting, part of it is squeezed out through this T bore, and escapes through three vertical ports in D into E, which is a hollow cylinder. Lest, however, solid particles should drop down into E, the three vertical ports through D are made, not in the central axis of C and D, but on the circumference of the T-bore, so that only liquefied matter finds its way through D into E. When some liquid escapes, the pressure in the press diminishes, and this pressure change is recorded by the pendulum manometer of Gebrüder Amsler, of Schaffhausen, who constructed the press, which admits of using pressures of 30,000 kg. Oil is compressed in a branch pipe (of copper) of the press, and this oil deflects a weighted lever; Jänecke describes this gauge, which is reliable within 0.05 per cent. at a pressure of 700 kg. per sq. cm. (9956 lb. per sq. in.), as a most essential part of his apparatus. A chrome-nickel resistance furnace can be slipped over the press, within its frame, and the temperature of the cylinder read off on a thermo-couple fitted into a bore of the outer steel cylinder. If there were really no friction, and if the press were hermetically tight, the observed pressures and temperatures would directly yield P^2 T curves; as it is, some calculations are required, but the concordance of the results and their agreement with other data speak well for the apparatus and method.

Jänecke first determined the melting-points of salts (gypsum, soda, borax, barium chloride, copper sulphate, &c.) which give up all or part of their water of crystallisation when fusing; carnallit (an important potassium salt, $KCl \cdot MgCl_2, 6\ H_2O$, (from Stassfurt) fused at 168 deg. Cent., and yielded crystals of KCl alone. Then transition points were studied, first of nitrates (K, NH_4, Ag), already investigated, and then of binary mixtures KCl-NaCl and AgCl-NaCl). In this latter case it was found possible to obtain, for the first time, complete diagrams of condition. The mixture KCl-NaCl has a minimum melting-point below which the mixture should "unmix"—*i.e.*, the constituents should crystallise separately. This was known to hold for KCl-NaCl, but not yet known to hold for AgCl-NaCl, and the whole separation curve of any isomorphous binary mixture had never before been plotted. Finally, Jänecke investigated the transition points of metals and alloys. He believes with E. Cohen that metals like tin, bismuth, antimony, lead, cadmium, copper, silver, and very probably many others, exist in different allotropic modifications, and he confirms most of the transition points of Cohen and others; the transition of silver into an allotropic modification at about 120 deg. Cent. had been suspected from thermo-electric studies, but not been otherwise established. But he differs from Cohen as to the theory, preferring, with A. Smits, to base his arguments on the "thermodynamic potential." Transitions are rarely marked, on his diagrams and heating and cooling curves, by quite sudden jumps; more frequently the change extends over a certain time interval, and the transition temperature is found by determining the intersection of the produced straight branches of the curves.

SECONDARY METALS IN THE UNITED STATES.

The importance of secondary metals—*i.e.*, metals recovered from scrap, sweepings, skimmings, dross, and other waste—cannot easily be estimated from statistics. A good deal of what is styled "waste" unfortunately remains waste, and is simply allowed to rust and rot without benefiting anybody. On the other hand, a considerable amount of secondary, not rarely fairly pure, metal forms a valuable raw material for further utilisation. How much scrap-iron is actually re-melted, and how much gold is recovered from old jewellery, sweepings, and photographic and dental waste, in the mints as well as in private establishments, it would be difficult to say. The statistics concerning the recovery of secondary metals in 1914, which J. P. Dunlop has collected for the United States Survey, do not give these figures, and they acknowledge that the data relating to other metals may not reveal more than half of the actual waste-metal trade. Yet those data, published in Paper I: 2 of the United States Geological Survey, as a reprint from the Mineral Resources of the United States, are interesting. Stocks of secondary metals, it is stated, were large at the beginning of 1914, prices low, and the trade, hence, smaller than in 1913; the prices improved, however. The recovery of lead, zinc, copper, tin, antimony, and aluminium aggregated 287,000 short tons, and the prices paid were only slightly lower than those for primary metals. The real figures are no doubt much higher, and that the importance of the waste-metal trade, and of the proper handling, grading, and classifying the metals, is now recognised in the United States is shown by the fact that a National Association of Waste-Metal Dealers was founded in 1914, which adopted a standard classification in December last. Exclusive of gold, silver, platinum, iron, steel, and ferro alloys, the value of secondary metals recovered in 1914 amounted to 57,000,000 dols., against 72,800,000 dols. in 1913—we give round figures. The industry is concentrated in the north-eastern section of the States, comprising Chicago and St. Louis, and a not inconsiderable number of the works concerned refine only secondary metals. The total quantity of copper recovered in 1914 was 127,883 tons; this estimate is made on the assumption that the re-melted brass had an average copper content of 70 per cent., and it represented 16.7 per cent. of the primary copper production of the year. All but 16,000 tons were recovered in plants dealing only with secondary metals. The amount of lead recovered was 61,000 tons, being 11,800 tons less than in 1913. The decrease was most noticeable in alloys (8000 tons), and largely due to slackness in building operations; the chief sources of old lead were old pipe, cables, batteries, lining of acid tanks, further babbitt and type metal; the secondary lead formed 11.3 per cent. of the primary refined lead. The output of secondary zinc (including that in brass) was 71,642 tons, equivalent to 20.3 per cent. of the primary zinc production; more than 20,000 tons of zinc were re-distilled from drosses and skimmings; three smelters in New Jersey, New York, and Pennsylvania, which confine themselves to drosses and skimmings, use large graphite retorts of 600 lb. or 800 lb. capacity, instead of the small clay retorts of smelters who treat ore or ore and drosses. The production of secondary antimony was 2646 tons, all but 1 ton coming from alloys; there is hardly any antimony ore, mined in the country, smelted in the United States, and the 2646 tons represent 35.2 per cent. of the imported ore. Neither were domestic tin ores smelted in the United States in 1914, though concentrates went from Nome (Alaska) to Singapore; the 12,447 tons recovered represented 26.2 per cent. of the imports; tin scrap left the works as tin oxide, putty powder, and chiefly as chloride, both stannic and stannous; some electrolytic tin powder went to secondary smelters. Large quantities of tin scrap and cans were utilised in the Western mines for the precipitation of copper from mine waters; the real agent in this precipitation is, of course, the iron, and the tin is lost. The recovery of secondary aluminium in pig or alloys amounted to 4522 tons; nearly all the alloy was one of 92 per cent. of Al and 8 of Cu. Most of the secondary aluminium came from clean clippings and borings, and was used for making castings; aluminium re-melted from clippings is not utilised for rolling sheet metal, lest the superficial oxidation of the old surfaces should cause splitting.

LITERATURE.

Land and Marine Diesel Engines. By Professor GIORGIO SUPINO. Translated by Eng. Lieut.-Commander A. G. BREMNER, R.N., and JAMES RICHARDSON, B.Sc. (Lond.), A.M. Inst. C.E. Published by Charles Griffin and Co., Limited, London. [Price 12s. 6d. net.]

IT is remarkable that in spite of the great strides made within the last few years in the construction of Diesel engines, and the consequent interest shown in this type of prime mover, a good text-book in English has not been forthcoming before this. There are text-books, of course, but these generally cannot be relied upon as guides to Diesel engine practice, and merely give a somewhat superficial insight into the general working principle of the type. The reason for this want of a good text-book is probably as stated by the translators in their preface:—"The time has not come, however, for a record based solely on British experience. Indeed, most of the British firms building oil-engines have, so far, based their practice on Continental systems. This is particularly the case with marine engines."

Professor Supino, the author, is an Italian engineer of high repute who has made a special study not only of the theory, but of the construction and running, of oil-engines, and his text-book is widely accepted on the Continent as a standard work. The choice of this work for translation is, then, particularly happy, and in the translation made by Eng. Lieut.-Commander A. G. Bremner, R.N., and James Richardson, B.Sc. (London), A.M. Inst. C.E., of Scotts', Greenock, the one more particularly versed in the performance of Diesel engines, and the other with their design and construction, the ideas and the lucidity of exposition of the author are faithfully retained.

The impression that this volume gives is that the theory and the practice are well intermingled, and the profuseness of illustration, so important a point when the many important details of the Diesel engine are considered, is well above the average of this class of text-book. The engravings, which cover the field of the general arrangement of engine, piping, and auxiliaries, of all the important details of valves, valve-gears, and include also many diagrams elucidating theoretical principles, comprise 19 plates and 380 other illustrations. There are, moreover, seven useful tables. Of these, one is devoted to a comparison of the floor areas occupied by suction-gas plants and Diesel engines respectively. In another the cylinder volume and rates of revolution adopted in marine-engine practice are tabulated, whilst others show the useful stroke of the fuel-pump at various loads, and give the dimensions required for scavenging-pumps. A routine schedule for the periodical inspection and overhaul of engine parts will also be found valuable.

Professor Supino's book will appeal with special force to those who wish to make a serious study of the Diesel engine as a piece of mechanism, and not merely as "a vile body" for essays on some elementary principles of thermodynamics. The thermodynamic side of the subject receives, of course, adequate treatment; but the special value of Professor Supino's work consists in the successful way in which he has attacked the more difficult kinematic and mechanical problems involved. In most cases these have to be solved by practical experience, the results of which are zealously guarded as valuable trade secrets. Those new to the Diesel engine will accordingly find invaluable Professor Supino's treatment of such problems as those involved in the operation, timing, and reversal of the valves. The whole of this exposition is adequately assisted by numerous and well-chosen illustrations.

It is unfortunate that, in the past, enthusiasm has led engineers to express views far too optimistic regarding the immediate future of the Diesel engine, and this procedure has had a detrimental influence upon progress. Throughout the work under review, it is pleasing to be able to state that whilst the lines of future progress are clearly indicated, and its possibilities by no means ignored, yet a conservative note is maintained with regard to the feasibility of so developing the type as to adapt it to the development of very large powers.

In the various chapters of Part I., the general theory of the Diesel engine is sufficiently and clearly indicated, and the calculation of cylinder dimensions is explained. Fuels and the suitability of oil-engines for various duties, with their advantages and disadvantages, are also discussed.

Part II. deals with the component units of the engine and their proportioning. In Chapters 7, 8, and 9 bed-plates, crank-cases, engine-framing, cylinders, crank-shafts, connecting-rods, pistons, cylinder-heads, valves, and fuel-injection valves are dealt with; and of particular merit are the illustrations, calculations, and discussion dealing with pistons, cylinder-heads, valves, and fuel-injection valves, all units of vital importance to the Diesel engine. In calculations of stresses it has to be borne in mind that there is no certain *à priori* method of determining safe working stresses in a new type of machine. In proportioning parts, foundry and machine-shop practice and experience with similar engines must always weigh heavily with the designer of the iron castings of engines which are subject to stresses and strains due to expansion by heat. Nevertheless, the discussion of the stresses consequent upon the pressures due to the working cycle are very valuable, and these have been carefully formulated and exemplified to serve as a basis for initiating designs, and for a comparison with the results observed in practice.

In Chapters 10 and 11 it is shown that when the functions to be accomplished by the cylinder-valves and the timing of the operations are understood and laid down, the design of a suitable gear to actuate the valves is no very abstruse problem. With this as an introduction, the principles involved in reversing the engine are explained, and as examples all the well-known reversing gears are taken in turn and compared with first principles. The following chapter, No. 12, is of special interest, dealing, as it does, with the design of fuel-injection pumps and fuel-regulation. It is not easy to obtain a complete and a clear understanding of this subject, and in this work thirty diagrams and many calculations are given with the object of treating this subject in a detailed and a definite way.

Subsequent chapters are devoted to a discussion of the accessories to the Diesel engine, such as compressors, air-reservoirs, scavenging-pumps, piping, &c., and of the buildings and foundations of land plants. A special chapter deals with marine installations and another with questions of tuning-up, test-bench, and acceptance trials. Of interest, especially to marine engineers and for reference, is the inclusion in this work of the latest rules, for the classification of marine Diesel engines, of Lloyd's Register of Shipping and of the British Corporation for the Survey and Registry

of Shipping. We believe that we are correct in stating that in the compilation of these a pioneering part was played by one of the translators of the present volume.

Professor Supino's work was clearly written in the first instance, and he has been extremely fortunate in his translators. The fact that both are recognised as specialists in Diesel-engine design and operation will probably go far to secure general assent to the nomenclature for the component details of the Diesel engine which they have adopted in their translation.

In connection with the metric system we quote from the translators' preface :—

"In the original work, calculations, dimensions, &c. are given according to the metric system. In this issue, British units are added where these tend to a readier understanding of the text. Calculations, however, have not been converted, as these appeal to the more expert reader, who is doubtless conversant with the metric system. A conversion table has been appended."

The value of the work is substantially enhanced by a comprehensive index.

Les Câbles Sous-Marins Allemands. Par CHARLES LESAGE. Inspecteur des Finances, Professeur à l'Ecole des Sciences Politiques. Paris : Plon-Nourrit et Cie. 1915. [Price 3.50 francs.]

THIS work was written and ready for the press before the outbreak of the war which has demonstrated the sincerity of the Entente Cordiale and united more closely the interests of the two nations. As no satisfactory reason is given for delaying the publication, or the selection of the precise moment for its issue, it is idle to speculate on the motives that have guided the author ; but the book is perhaps the more valuable, as it may be supposed to exhibit the attitude of the French mind towards the legitimate enterprise of this country at a time when unexcited by abnormal conditions. The author writes coldly, and if there is no explicit disapproval of the policy adopted and pursued by the English companies in the management of their submarine telegraphic communications, there is evidence of irritation or bitterness at what is described as "l'hégémonie telegraphique de l'Angleterre," "le monopole britannique," and similar expressions. A main object is to show that Britain has been worsted in the industrial warfare with Germany, and it is impossible not to recognise the veiled satisfaction with which the author claims that German ambitions are on the point of being attained. "Dès aujourd'hui, en presence des résultats acquis, on peut dire que, sur le terrain restreint de combat qu'offrait l'industrie telegraphique, les Allemands l'ont emporté."

It is intimated that Germany was unduly obstructed or hampered in her industrial development by having to use English cables in her communications with America, and her nascent colonies, and was obliged to seek independent means for securing the speedy and accurate delivery of her messages. There is no question but that Germany was quite within her rights in providing additional cables, and in asserting those rights she proved herself alert, enterprising, astute and successful. She is entitled to the tempered congratulations that M. Lesage offers on the result of a policy she steadily pursued, having for its culmination the emancipation from British domination. Germany's grievance is not so apparent to us as to the author, whose strictures and criticisms we accept as those of a candid friend. If he wounds our self-complacency, his censure falls at times no less harshly upon his own countrymen, and therefore we must not complain, if he recognises rather grudgingly the efforts and the sacrifices English scientists and capitalists made in order to carry submarine telegraphy to a successful issue. The author aimed at preserving a position of detachment, and, perhaps, he has not been unsuccessful.

The author does not touch upon the technique of cable manufacture, or on the shipping and laying of the finished product. He is engrossed solely by the political and financial problems, and the devices for overcoming the difficulties that are raised by rivals or opponents. He emphasises the important part that submarine telegraphy may be made to play in the expansion of nations, and shows how at different times the chancelleries of Europe have been disturbed by proposals for new cables, how the artificial grouping of Powers has been influenced, and how a distrustful jealousy has formed new combinations and sought fresh alliances. In sufficient detail, and with great clearness, the author traces the steps by which, in spite of opposition from England, Germany, through her dogged perseverance, by the flexibility of her diplomacy, and by the careful manipulation of her home resources, has achieved success. Doubtless she has been urged towards her goal by her envy and jealousy of this country. She has known how to turn to account the latent, but profound, hatred that permeates all classes of society, and armed with this spur to her activity, she has established a firm and secure telegraphic link that unites and gives additional strength to the military and commercial forces scattered throughout the globe. That we have been the principal antagonist and have suffered most by her rivalry must not blind us to the magnificence of the effort she has made, or prevent us acknowledging the efficacy of the machinery she has employed. Let us remember that Germany was late in entering into competition, she had to gain her experience and train her men, nevertheless in all the submarine connections Germany has effected in the last eleven years, the cables have been made in her own country, carried on German ships built for the purpose, and operated by German workmen. Only by appreciating the extent of the work achieved can one grasp the importance attached by the Government to the construction of this submarine network of cables, and the vigour of the effort destined to realise the ambitious conceptions of the Emperor.

The mere length of the cable submerged within the last fifteen years, 38,000 km., tells us much, the considerations of the routes much more. At the beginning of this century Germany could communicate with her emigrants on the American continent and with her African colonies only by English cables ; she possessed no telegraphic communication with the Polynesian Islands that she had purchased or acquired by agreement. Kiao Tchau could be reached only by borrowing the telegraphic routes in the hands of either the British or the Russian nation. At the commencement of the war Germany was connected to the United States by two cables passing through the Azores, and with Brazil by the Borkum-Pernambuco cable. Togo and the Cameroons had been for some time joined to her telegraphic network, and progress had been made to bring German South-West Africa into independent communication with the parent country. In the Pacific Ocean, cables starting from the colony of Kiao Tchau, and passing by the Caroline Islands, were joined to the neutral Trans-Pacific American line, while the other colonies in the Eastern Ocean, by availing themselves of the wireless equipment, were in touch with the same trunk cables. More than this, the expansion of commercial activity and the acquisition of political prestige required, or were thought to require, direct communication with Constantinople and Egypt, and through the kin1 offices of Roumania a cable was carried through the Black Sea, dispensing with the assistance of stations in the possession of actively competing countries. We may say here, *en passant*, that before the war all these schemes paid the shareholders very good dividends, and in cases where the State was prepared to subsidise an undertaking such assistance has rarely been needed.

The mechanical work, onerous as it has been, and necessarily involving heavy financial transactions, has been probably less than that encountered in overcoming the diplomatic difficulties which had to be removed in order to complete the cable network that would satisfy German ambition and necessities. The opposition raised by vested interests has been great and continuous, occasioning delays by raising objections that at times seemed insuperable. The German colonies were acquired as opportunity offered, are widely scattered, and do not offer a convenient seaboard for landing submarine cables, or erecting stations from which a telegraph system might conveniently radiate. It is a far cry from Emden to the Azores, for example, and Germany would fain have broken the line on our Cornish coast, but such hospitality was denied. Even to avail herself of the Azores the kindly permission of the Portuguese had to be solicited. Vigo offers evident advantages for certain routes, but again its possible use depends upon the good will of Spain. Look in what direction Germany will, some nation has to be entreated, and some bargaining effected, some jealousies to be appeased, and some suspicions allayed. And Germany fought her way through all obstacles, overcame all the secret and open opposition that was offered, struggled against fears and prejudices, and was victorious over all rivals. How this end was accomplished is the tale M. Lesage tells, recalling many forgotten pieces of history, and illustrating the intricate paths of diplomacy. We are permitted to see German agents now trafficking with the Danish and again with American companies ; in alliance with the Dutch, the German-Netherland Company is formed, and undismayed by repeated failures and the improbability of success, the French Government is approached and found willing to provide facilities of great moment. Germany has known how to wait, how to influence, and how to drive forward at a critical time ; she has invented new methods of exploitation by creating and subsidising companies of mixed nationality, so powerful that they can compete with organised Governments. Whether she will be permitted to reap all she has sown, to profit by all she has plotted, is the problem which is being fought out on the battlefields of Europe and Asia. Whatever may be the issue, the price that Germany will have to pay for the luxury of satisfied ambition will be heavy and self-consuming, and her cables will never be useful in war until she has command of the sea.

BOOKS RECEIVED.

Willing's Press Guide and Advertisers' Directory and Hand-Book, 1916. London : James Willing, Limited. [Price 1s.]

British Meteorological and Magnetic Year-Book, 1916. Part IV., Section 2. *Hourly Values from Autographic Records : Geophysical Section*, 1913. London : The Meteorological Office, Exhibition-road, S.W. [Price 5s.]

The Factory, Truck, and Shop Acts. By the late ALEXANDER REDGRAVE, C.B. Twelfth Edition. By CHARLES F. LLOYD. *Statutory Orders, Regulations, Special Rules, and Forms.* Revised by W. PEACOCK. London : Shaw and Sons and Butterworth and Co.

Oil-Fuel Equipment for Locomotives and Principles of Application. By ALFRED H. GIBBINGS, Assoc. M. Inst. C.E. London : Constable and Co., Limited. [Price 7s. 6d. net.]

Transactions of the Institution of Civil Engineers of Ireland. Seventy-ninth Session, November, 1914, to May, 1915. Vol. XLI. Dublin : John Falconer, 53, Upper Sackville-street.

The Brass-Moulder Illustrated : A Practical Guide for the Apprentice and Young Journeyman. By ALEX. PURVES. With 85 illustrations. London : E. and F. N. Spon, Limited ; New York : Spon and Chamberlain. [Price 3s. net.]

The Petrol-Engine : A Text-Book Dealing with the Principles of Design and Construction, with a Special Chapter on the Two-Stroke Engine. By FRANCIS JOHN KEAN, B.Sc. With 71 illustrations. London : E. and F. N. Spon, Limited ; New York : Spon and Chamberlain. [Price 4s. net.]

Commercial Motor-Drivers' Hand-Book. A Manual and Companion for Drivers of Petrol, Steam, and Electric Road Motors. By GEORGE W. WATSON. London : The Commercial Motor-Users' Association (Inc.), 83, Pall Mall, S.W. [Price 1s. 6d. net.]

An Introduction to the Mechanics of Fluids. By EDWIN H. BARTON, D.Sc. London, New York, Bombay, Calcutta, and Madras : Longmans, Green and Co. [Price 6s. net.]

Stationsdeckungs- und Blocksignale. Ein Beitrag zur Sicherung des Eisenbahnbetriebes. Von Dr. Ing. A. GUTZWILLER. Zürich und Leipzig : Verlag Gebrüder, Leeman and Co. [Price 4.80 francs.]

Origen y Progresos de las Corazas de los Buques. Por el Capitan de Navio de la Armada Italiana, Sr. ETTORE BRAVETTA. Madrid : Imprenta del Ministerio de Marina.

Credit, Industry, and the War ; being Reports and other Matter Presented to the Section of Economic Science and Statistics of the British Association for the Advancement of Science, Manchester, 1915. Edited by ADAM W. KIRKALDY, M.A. With a Preface by WILLIAM ROBERT SCOTT, M.A. London : Isaac Pitman and Son, Limited. [Price 2s. 6d. net.]

The British Coal Trade. By H. STANLEY JEVONS. London : Kegan Paul, Trench, Trubner and Co., Limited. [Price 6s. net.]

Engineering for Architects. By DE WITT CLINTON POND, M.A. London, Toronto, Melbourne and Bombay : Humphrey Milford, Oxford University Press ; New York : Columbia University Press. [Price 8s. 6d. net.]

SPONTANEOUS OXIDATION OF PYRITES.—A case of spontaneous oxidation of iron pyrites recently came before the law courts at Hamburg ; the facts dated several years back, and have nothing to do with the war. The oxidation did not cause a fire, but it destroyed the iron barge on which the iron sulphide was being shipped. The circumstances are, perhaps, somewhat unusual ; but they nevertheless suggest caution. The pyrites were put on board at Hamburg in the beginning of November, to be shipped up the Elbe ; owing to various causes—low water being one of them—the barge was delayed, and the pyrites were not discharged till the end of February. The mineral had not been properly covered in, the rain and air had converted some of the sulphide into acid, and the iron had been badly corroded.

ROYAL METEOROLOGICAL SOCIETY.

THE annual general meeting of this Society was held on Wednesday, the 19th inst., at the Surveyors' Institution, Great George-street, Westminster, Major H. G. Lyons, F.R.S., President, in the chair.

The report of the Council for 1915 was laid before the Fellows, and the Symons Memorial Gold Medal, which is awarded biennially for distinguished work in connection with meteorological science, was presented for transmission to Dr. C. A. Angot, Bureau Central Météorologique de France. The President (Major H. G. Lyons, F.R.S.) delivered an address on "*The Winter Climate of the Eastern Mediterranean*," of which the following is an abstract:—

"At the present time, when the area of the Eastern Mediterranean is of special interest, I would direct your attention to its climate, which must exercise great influence on the naval and military operations now in progress. During the last fifteen to twenty years a large number of meteorological stations have been in operation, and from their published results we have an accurate and detailed knowledge of the meteorological conditions which prevail there at the different seasons of the year. These vary from the true continental climate of the Balkans, with its low winter temperatures and moderate rainfall at all seasons, to the Mediterranean climate of Southern Greece and the Levant, with its mild winter, hot summer, and a strongly marked rainy season in winter. In Lower Egypt these characteristics also prevail in a more intense form.

"The geographical character of the Balkan Peninsula and the surrounding seas, Syria and Palestine, and Lower Egypt, affect to some extent the general climatic conditions, and these are described. The temperature in the Balkan region in winter is frequently very low, descending to 0 deg. Fahr., and often below this at many stations, while frost occurs often at inland Greece and occasionally throughout the Eastern Mediterranean. The most severe weather occurs when anticyclonic conditions with clear skies and light winds prevail in the Balkans; the air then falls to a very low temperature, and as a result streams off the highlands down into the low-lying Ægean Sea as a strong cold northerly wind which often reaches gale force. January is the coldest month, and February differs but little from it, the first marked departure from winter conditions occurring in March. By this month, too, the waters of the Mediterranean begin to grow warmer. During the winter months they have been from 5 deg. to 10 deg. Fahr. warmer than the coasts, where, therefore, the winter climate is much milder than inland; but in March the difference becomes very small, and disappears at many places as the land is growing rapidly warmer. In winter rainfall is heaviest on the western shores of Greece and Syria, and markedly less on the eastern coasts. The Balkan rainfall has a maximum in November, and afterwards decreases slightly, but it is not heavy at any time. Rain falls during the passage of depressions from the Mediterranean which pass from west to east, bringing cloudy, mild weather, rain, and strong winds. Rainfall decreases southward, and in Lower Egypt the amount is insignificant. The normal air-circulation of the Eastern Mediterranean is simple in its general outlines. Northerly winds blow over Greece and the Ægean Sea, becoming northwesterly in the Mediterranean, and westerly on the Syrian coast. In Egypt northerly winds prevail. This arrangement, which follows from the mean distribution of pressure in winter, is, however, greatly modified by the frequent passage of depressions along the Mediterranean from west to east. Many pass over the Balkans to the Black Sea and Southern Russia, causing strong southerly gales in the Ægean Sea, with rain and mild, unsettled weather for two or three days. Others cross Greece and the Ægean, where strong southerly winds blow as they are approaching, which usually veer to the north-west on the following day. Others again pass to the south of Greece, sometimes skirting the Egyptian coast, and cause south-westerly gales and stormy weather in the Eastern Mediterranean and Levant, and northerly winds in the Ægean Sea. An analysis of the observations shows that northerly winds, which cause rough seas in the Ægean Sea during the winter months, are more frequent than southerly winds in the proportion of 2.5 to 1; and since many of these northerly winds are due to cold air pouring down from the Balkan highlands, the northerly winds may continue for a week at a time, while southerly gales rarely last for more than two days, unless a second depression is closely following the first."

IRON AND STEEL IN JAPAN.—Iron and steel pig and ingots were imported into Japan in 1914 to the extent of 178,639 tons, valued at 821,400*l*. The corresponding imports in 1913 were 278,817 tons, representing a value of 1,264,300*l*. Of the imports of 1914. 62,556 tons, of the value of 293,200*l*., came from the United Kingdom, as compared with 103,473 tons, valued at 488,400*l*., in 1913. Other imports in 1914 were:—From India, 31,183 tons, as compared with 81,171 tons; from China, 54,750 tons, as compared with 59,469 tons; from Sweden, 16,044 tons, as compared with 16,011 tons; from Germany, 7524 tons, as compared with 14,847 tons; and from other countries, 6582 tons, as compared with 3846 tons. It will be observed that there was a general falling-off in the imports except in the case of Sweden. The Indian contribution from the Tata and Bengal iron works, which had considerably increased during the two previous years, received a sudden check in 1914. It is expected that the war will have the effect of increasing competition from America, which is likely to be developed by the advantages of the Panama route; but German industrials will suffer from loss of trade, and this will benefit both Great Britain and the United States.

TESTS ON CONCRETE.

TO THE EDITOR OF ENGINEERING.

SIR,—Through the columns of your journal I beg to draw the attention of those engaged on researches in concrete, as well as others equally interested, to a few points that numerous tests which I have made from time to time suggest to me.

First and foremost, I wish to make a strong appeal to those engaged on concrete research not only to give the usual information, such as proportions of mix, sizes of material, age, &c., but to give also the following very necessary item:—*The percentage of cement content in the finished concrete*, or, in the form of a fraction:—

$$\frac{\text{Volume of cement used}}{\text{Volume of finished concrete}}$$

In order to show the need for this I will state that out of twenty mixes of concrete, using different materials, to the common proportions, 1-2-4, and all made for the same purpose and at the same time, there was produced a minimum ratio $\left(\frac{\text{volume of cement}}{\text{finished volume}}\right)$ of 1 to 5.6, and a maximum ratio of 1 to 4.33, these being based on the dry volume of cement introduced. If based on the wetted volume of cement, the ratios become 1 to 8 and 1 to 6.2.

The next point is that the one with the least cement was weakest, while the one with most was strongest. The weakest was gravel, and the other stone. Now that, to some, condemns gravel; but they are unfair. Give the gravel an equal chance by allowing it as much cementing material for the finished volume of concrete produced as with the stone, and also by reducing the ratio of sand to large material; it will be found, all other things being equal (materials of approximate equal size, equally clean, and the same treatment) that practically no difference will exist. Two reasons exist for the suggestion to use less sand:—

(*a*) Gravel contains (usually) a smaller percentage of voids than stone.

(*b*) Gravel is more easily "lubricated" into position by the sand and cement than is stone, because of the rounded particles.

The third point is that on the usual specification for 1-2-4 concretes, the contractor using gravel can produce a structure of a given size with the use of 100 tons of cement; whereas another would use 128½ tons in a stone concrete.

There are two ways of looking at this—

(*a*) The contractor's.

(*b*) The engineer's.

The contractor could save 28½ tons of cement, plus the saving in not having to handle this quantity—a total saving worth effecting. The engineer can be sure that his structure is almost proportionately weaker.

It was the reading of a report of tests on (1) gravel, (2) limestone, and (3) slag, as large aggregates all mixed 1-2-4, where the strengths were low for gravel, medium high for limestone, and high for slag, that prompted me to write you. Should this catch the tester's eye, I beg of him to make up another batch of each, but with *equal percentages of cement* and of *equal working consistency*, and report once more with the old figures alongside.

Yours faithfully,

H. C. JOHNSON.

Engineering School, University College, Cork,
January 11, 1916.

ELECTRICAL POWER PLANTS IN THE THAMES.

TO THE EDITOR OF ENGINEERING.

SIR,—In a recent number of ENGINEERING there appeared an interesting leading article referring to reports by Messrs. Merz and McLellan and H. F. Parshall upon the supply of electricity to London. From these reports it appears that there are from forty-five to sixty-five electrical power-stations within the district, depending upon the area considered. Your comment that "London is the outstanding example to the world of how electricity supply should not be conducted" is very impressive. From the Merz and McLellan report it appears that an annual saving of 170,000*l*. in working costs can be made by modernising the system after paying capital costs, and from Mr. Parshall's report that a saving of 550,000 tons of coal per year can be made, which has a value of some 400,000*l*.

The electrical supply system in London, as in all other places, has grown from small beginnings, resulting in out-of-dateness, duplication, and inefficiency, and in many cases it is, without doubt, difficult to obtain condensing water and coal. There comes a time in all such instances when nearly everything must be thrown away, and apparently the time is approaching when this is to be done in London. In thinking over an ultimate solution of this problem of magnitude and efficiency, the following plan has occurred to me, and has, I believe, many desirable features.

The project is to place several of what, for want of a better name, I shall call "express power-stations," in the middle of the Thames. Between the Waterloo and Blackfriars Bridges the Thames has a width of about 850 ft., and here there might be formed a narrow island, say 100 ft. wide, on which a long power-station could be placed. The up-stream end could be shaped like the bow of a boat in order to interrupt the flow of the water as little as possible, which would be no more, probably, than that caused by the piers of some of the bridges. The down-stream end could be divided for the accommodation of coal and ash-barges. There would be unlimited condensing water right at hand, and this would be taken in on one side of the station and discharged on the other. The wires would pass to both sides of the river through tunnels, and make-up feed-water, if the river water is unsuitable, could come in the same way. As the Thames substantially divides London equally, both sides would be conveniently served.

The condensing apparatus would be in the basement of the building, mostly below the water-line; in the first storey there would be immense steam-turbines, in the next there would be boilers, and above there would be coal. It might, in fact, be necessary to use more than two storeys for turbines and boilers.

The boilers could be of the double Stirling type, as used in Detroit, having some 30,000 sq. ft. of heating surface each, made for the highest desirable pressure and superheat, and each should be equipped with two underfeed forced-draught stokers of the Taylor type, capable of driving the boilers to fully three times their rated capacity at times of peak load, and thus reducing capital cost. Such stokers would respond to sudden demands in astonishingly quick time, and be at all times smokeless. These features enable a minimum of boilers and space to be used, and are of the utmost importance. The chimneys would not extend above the top of the building and would be invisible.

Such plants could be placed at intervals in the river, could be extended, and if of suitable design would be as beautiful as most other buildings, and when viewed from one side of the river would be as sightly as the other side in many places.

The question of the supply of coal naturally comes up, and this could be carried out in a manner which would relieve present terminal congestions. A place somewhere on the river bank below London could be secured for a grand coal terminal, with mechanical means of grasping railway coal-wagons and dropping or sliding their whole contents into barges, which would be towed to the power-stations. There should also be ample room for coal storage at the terminal to provide for stoppage of shipments, and there should be machinery for handling it in the most advantageous manner.

The navigation of the Thames would scarcely be interfered with, as craft going in either direction naturally occupy the right-hand half of the river, which would only be about 50 ft. narrower than now. Difficulty in carrying out this scheme would naturally be encountered with the Thames Conservancy Board, but perhaps in time it could be overcome in view of its manifest advantages.

Yours truly,

F. W. DEAN.

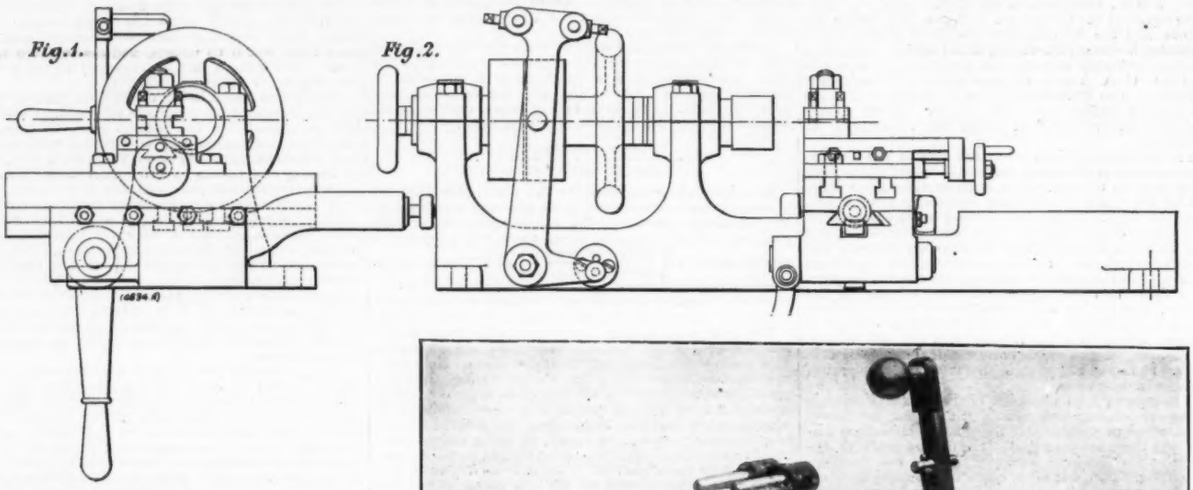
53, State-street, Boston, Mass., December 27, 1915.

THE UNITED STATES NAVY.—In an article dealing with the five-year shipbuilding programme of the United States, *The Iron Trade Review*, Cleveland, Ohio, says that American private shipbuilding yards contend that, while the Navy Yard figures are lower than theirs, it is well known that the bids of the Government plants do not represent the total cost for a battleship. It is on these grounds that the private plants are showing an inclination to forego Naval work until the Navy Department officials come to a realisation of the fact that it is quite impossible for private enterprise to compete with Government yards under present conditions. Already the Navy Department appears to be worrying lest the Navy yards will be unable to build the two battleships recently awarded without long delays, as is characteristic of Government work.

THE L.C.C. REGULATIONS RELATING TO REINFORCED CONCRETE.—A special importance attaches to the rules governing the use of reinforced concrete just issued by the London County Council, since they are extremely likely to be adopted *en bloc* by building authorities throughout the country. Rules of this kind though necessary, owing "to the hardness of man's heart," are not, of course, free from certain drawbacks, and unless provision be made for frequent revision may, as knowledge develops, come ultimately to constitute a serious drawback in the paths of progress. In general building regulations are bound to assume as their basis material of fair average quality, and thus indirectly serve to discourage the use of the very best procurable. This disadvantage is hardly remediable without throwing an intolerable strain on the surveyors or engineers of the local authority, who indeed are themselves in general also of merely "fair average quality," so that a discretion which might quite properly be exercised by, say, the late Sir Benjamin Baker cannot safely be entrusted to the local surveyor to Muggleton-on-sea. Fixed rules are accordingly necessary, and that being so, the L.C.C. rules may be taken as fairly in accord with good modern practice and will certainly prove most serviceable as a guide to architects and engineers. These will also find useful a little hand-book to these regulations just issued by Messrs. B. T. Batsford, Limited, the author being Mr. E. T. Andrews, who is well known as a writer on the theory of structures. The explanations given in this hand-book of points which some may consider obscure in the wording of the regulations will certainly prove most useful. Worked-out examples are given of the formulæ embodied in the regulations, together with a number of convenient diagrams, with the aid of which arithmetical work may in certain cases be considerably reduced and the danger of a numerical slip avoided. Curiously enough, however, Mr. Andrews does not discuss in these notes the effect of an eccentric load on a column for which, according to the regulations, due provision must always be made. Some discussion of this rule would certainly seem to be in order, since some very erroneous methods of treatment have been advocated by architects and accepted by borough surveyors. In some cases the error involved has been as much as 30 per cent.

TRIMMING-LATHE FOR SMALL PARTS.

CONSTRUCTED BY THE SELSON ENGINEERING COMPANY, LIMITED, ENGINEERS, LONDON.



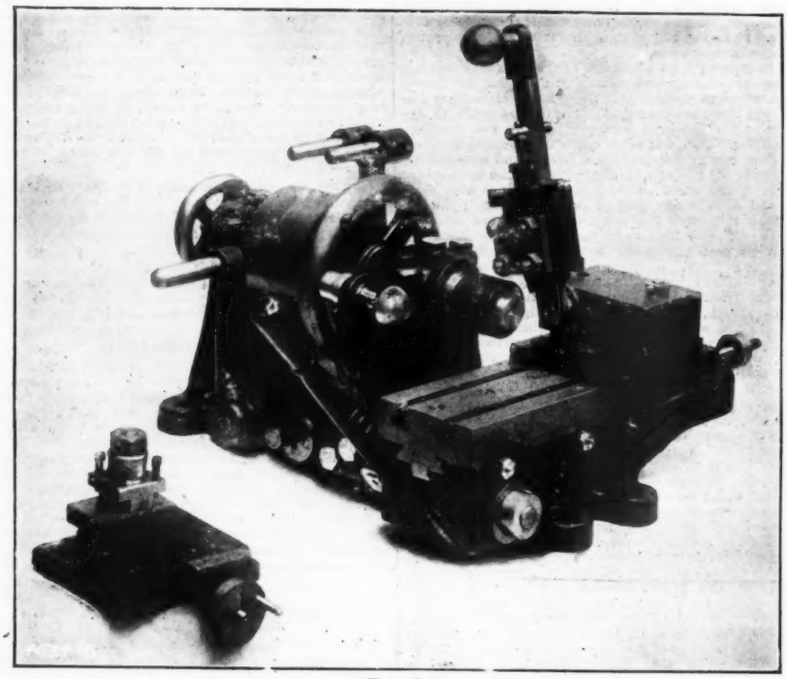


FIG. 3.

THE accompanying illustrations show a small trimming-lathe, designed and sold by the Selson Engineering Company, Limited, of 85, Queen Victoria-street, London, E.C., for forming and finishing operations on small parts, such as screws and knobs, which have been machined on capstan lathes or automatic machines.

Figs. 1 and 2 are respectively end and side elevations of the tool, while Fig. 3, which is reproduced from a photograph, gives a good idea of its general appearance. As will be seen, it is driven by a pair of fast and loose pulleys, which are 4 in. in diameter and 1¼ in. wide, and hand-wheels are also provided to facilitate the turning of the spindle by hand. As originally designed, the belt-shifter was made as shown in the drawings, Figs. 1 and 2—*i.e.*, the belt-fork was placed in front of the pulleys, but a more convenient arrangement, shown in Fig. 3, has now been substituted, the belt-forks being placed behind the pulleys and operated by a handle in front. If desired, a cone-pulley and counter-shaft can be supplied in place of the fast and loose pulleys. The spindle, which is hollow so that draw-back collets can be used, runs in phosphor-bronze bearings, and the thrust is taken on a hardened steel ring; the diameter of the hole through the spindle is ⅛ in. The slide-rest is moved in a transverse direction by a lever and steel rack and pinion, which gives a total movement of 1⅞ in.; it is fitted with a turret tool-post, taking two tools of ⅜-in. square steel. The top slide is adjustable longitudinally along the carriage for a distance of 1½ in., and positive stops are provided for both longitudinal and transverse movements. The swing over the carriage is 3½ in., and over the top slide 2¼ in.

In Fig. 3 the lathe is shown fitted with a radius turning attachment, of which the construction and method of operation will be clear from an inspection of the illustration. This renders the machine particularly well suited for finishing fuse-caps and other objects having spherical surfaces. On the whole, it seems to be a very useful little tool, for which many applications can be found in the manufacture of munitions.

PERSONAL.—Robert Matthew Raymond, a prominent mining engineer, has been appointed Professor of Mining in the Columbia University Graduate School of Mines.

BRITISH TRADE EXHIBITION.—An exhibition building, costing 200,000*l.* and covering an area of 610,000 sq. ft. (3½ times the size of Olympia), will be opened as the Palace of Industry early in 1917, at Willesden Green, in North-West London. It is to be known as the Industries of the Empire Fair. It will be the greatest trade exhibition ever organised, and is a worthy outcome of co-operative action on the part of the principal trade associations of this country. Between 2000 and 3000 exhibitors and upwards of 70 distinct trades will be represented. The frontage of the stalls will approximate 12 miles in length. This fact has rendered necessary, for the convenience of the thousands of British, Colonial, and foreign buyers who intend to be present, the formation of sixteen different sections. The Advisory Council of the Industries of the Empire and Fair consists of representatives of the principal trade associations and manufacturing houses of Great Britain. One object of this display of British goods (it is to be solely a British Exhition, no foreign exhibits whatever being allowed) is to put an effectual barrier between this country and the traders of Germany, who, whilst the war is in progress, are hoarding great stocks of goods in the hope of dumping them down in this and in certain neutral markets directly peace is declared. The administrative offices are in Lincoln House, High Holborn, London, W.C.; the profits of the Exhibition will be refunded to the exhibitors in the form of a bonus.

PORT SAID.—There was a slight falling off in the volume of business at Port Said in 1914 as compared with 1913; but notwithstanding the depression caused by the war there was an increase over 1912 (the next best year) of £E159,000. Until the outbreak of the war the trade of Port Said was increasing; but it immediately felt the influence of war dislocation and depression. The imports of coal into Port Said in 1914 were 1,774,814 tons, or 182,509 tons less than in 1913. This was due to a diminution in deliveries during the last five months of the year, and to high coal freights which prevailed during the same period. Coal freights averaged from January to July, 1914, inclusive, 9*s.* per ton, and from August to December, 1914, inclusive, 30*s.* per ton from Cardiff, and 1*l.* 12*s.* 6*d.* per ton from the Tyne. The average price of Cardiff coal at Port Said during the latter period was 2*l.* 14*s.* per ton, and of North Country coal 2*l.* 10*s.* 6*d.* per ton. For some time after the outbreak of war homeward freights from India averaged as low as 12*s.* per ton, and it became more advantageous to sacrifice a part of the cargo space to cheaper Indian coal, thus obviating the necessity of coaling at high rates at Port Said. An improvement has since occurred in this respect, as homeward rates from India have risen to 2*l.* 10*s.* per ton. The manufacture of patent fuel is assuming importance, sales in the interior of Egypt amounting in 1914 to between 60,000 and 70,000 tons. From January 1, 1914, the maximum draught of vessels using the canal was increased by 1 ft. to 29 ft., and the draught was further advanced in 1915 to 30 ft. The minimum width of the canal, at a depth of 32 ft. 10 in., is now 147 ft. 9 in., and the maximum width, exclusive of Lake Timsa and the Bitter Lakes, is 328 ft.

THE DEVELOPMENT OF SZECHUAN (CHINA).—Szechuan province, the largest and wealthiest province in the Chinese Empire, offers, says *The London and China Telegraph*, a magnificent market for British manufactured goods, particularly machinery, but it is noticeable that very little machinery has been hitherto imported into the province, and still more noticeable is the fact that only a small portion of the machinery imported in recent years is of British origin. Our contemporary says the province is self-supporting, and suggests that at a comparatively small cost a foreigner with a couple of good Chinese assistants could work very profitably in the interests of British manufacturers and prepare the way for some definite scheme in the future. He would have to do considerable travelling and keep in touch with Chinese who are contemplating some industrial enterprise. It is very rarely that a Chinese will come to terms at once with a foreign engineer for the purchase of plant. In the first place the estimate is generally much higher than the Chinese bargained for. He should therefore be given full information about his requirements, and left to consider the thing for a few months, after which he should be re-visited, and assisted in every possible way to arrive at a conclusion in the matter. The foreigner should be assisted as far as possible by the Consulates, and would soon become known to the Chinese officials and merchants throughout the country as an official representative of British manufacturers. Such a representative, backed up by British engineering firms collectively, could not fail to produce results which would fully justify the expense incurred. The main object would be to endeavour to turn as much engineering business as possible into British channels, and to see that no scheme is put forward requiring outside assistance which does not come to the knowledge of the British investor

ELECTRICAL RAILWAYS.*

By HENRY METCALF HOBART, M. Inst. C.E.

(*Continued from page* 48.)

ROLLER PANTOGRAPH COLLECTORS.

EACH of the 72-ton freight locomotives is fitted with a roller pantograph trolley. The additional four freight locomotives are each fitted with two pantographs, but only one is in use at a time. All the heavier freight trains are headed by two 72-ton locomotives, and consequently the current for the heavier freight trains is collected at two contact points. The eight motors on two locomotives have an aggregate continuous capacity of 2160 horse-power. At an efficiency of 0.85 per cent. for the electrical equipment on the locomotive, the corresponding current to be collected is

$$\frac{2160 \times 746}{0.85 \times 2400} = 790 \text{ amperes.}$$

The general practice during starting and accelerating is to keep the current at not more than 500 amperes per 72-ton locomotive.

The limiting currents which have been mentioned rarely obtain. Under usual service conditions the average current collected per pantograph is only some 400 to 500 amperes when starting and when ascending grades. When, as is usual, a freight train is headed by two 72-ton locomotives, the two pantographs are connected in multiple by a bus-line run on the top of the locomotives, with a jumper for effecting the connection between them. Each passenger locomotive is equipped with two pantographs, but only one is in use at a time.

THE CHICAGO, MILWAUKEE AND ST. PAUL 3000-VOLT ELECTRIFICATION.*

In the map in Fig. 7 will be seen, represented by light lines, the main line of the Butte, Anaconda and Pacific Railway, the electrification of which has been described in the preceding pages. The heavy lines represent a 440-mile section of the Chicago, Milwaukee and St. Paul Railway. This 440-mile section comprises (including yards and sidings) 650 miles of single track, and runs from east to west, extending from Harlowton, in the State of Montana, to Avery, in the State of Idaho. The line from Harlowton to Avery comprises four divisions,

Fig. 7.

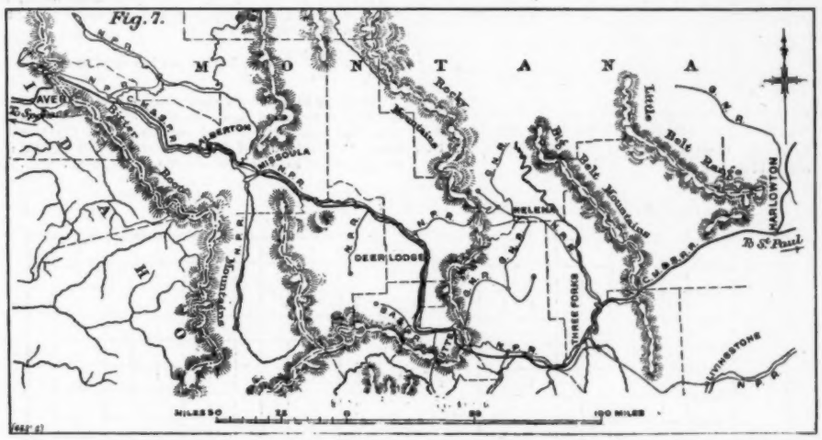


FIG. 7. MAP SHOWING THE 400-MILE SECTION OF THE CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY (AVERY TO HARLOWTON) IN COURSE OF ELECTRIFICATION; ALSO THE BUTTE, ANACONDA AND PACIFIC RAILWAY.

Fig. 8.

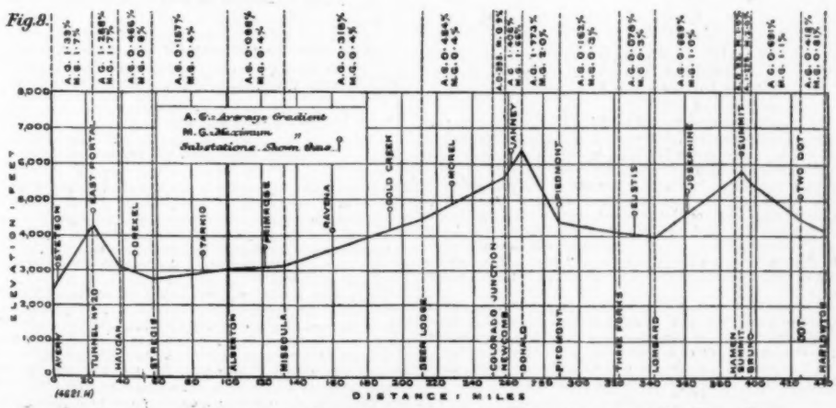


FIG. 8.—PROFILE OF ELECTRIFIED DIVISIONS OF CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

Thus currents as great as about 800 amperes will be collected from the 4/0 trolley-wire, and on the reasonable assumption that the current will not divide equally between the two pantographs, it is incumbent upon each pantograph to be capable of dealing with current up to 500 amperes, in the service on the Butte, Anaconda and Pacific Railway. The 4/0 trolley-wire will have a rise of about 180 deg. Cent. when carrying 1000 amperes continuously in the open air. For this temperature rise it can carry a considerably greater current for a few minutes. It is to be noted that the current will flow to the points above the locomotives from both directions from the nearest feeding-points behind and ahead of the locomotives. Taking these data into consideration, it will be seen that the system could deal with four 72-ton locomotives simultaneously located between two adjacent feeding points, and requiring an aggregate of some 2000 amperes. The three Smelter Hill sub-station sets deliver, when all in service, 1250 amperes at their continuous rated load, but they are capable of providing (3 × 1250 =) 3750 amperes for five minutes.

* James Forrest Lecture, delivered before the Institution of Civil Engineers, on Tuesday, December 14, 1915. In the enforced absence of Mr. Hobart in America, this lecture was delivered on his behalf by Mr. John A. F. Aspinall, M. Inst. C.E.

the average length of each division amounting to 110 miles. Avery is only some 400 miles from the Pacific Coast, and in the event of satisfactory experience with electric operation of the 440 miles between Harlowton and Avery, the railway contemplates continuing the electrification to Seattle, on the coast, which will make a total distance of 850 miles from Harlowton. The railway commenced in the latter part of 1914 to put its electrification plans into effect, and forty-two electric locomotives, each weighing 250 British tons, together with machinery for fourteen sub-stations and material for the transmission and distribution of the electricity, are now being supplied. In the spring and summer of 1915 the 113 miles between Three Forks and Deer Lodge were equipped for electrical operation, and it is intended that by the beginning of 1916 all trains passing over this division shall be propelled exclusively by electric locomotives. The electricity will be supplied under a contract with the Montana Power Company, which has ten hydro-electric plants in this region.

These ten electricity-supply stations will, when completed, have an aggregate installed capacity of over 200,000 kw. The Montana Power Company supplies electricity to consumers distributed over many parts of the States of Montana and Idaho. The total water-storage capacity provided in this system is over 400,000 acre-feet, which, with the other arrangements provided by the power company, affords ample assurance of an uninterrupted supply of electricity at all seasons.* The railway company is providing a 100,000-volt tie-in transmission line. The power company will deliver the electricity into this tie-in transmission line at several feeding-in points. The price of the 100,000-volt 60-cycle three-phase electricity delivered to the railway company at these feeding-in points is 0.26d. per kw.-hour. The railway sub-stations are supplied from the 100,000-volt tie-in line, which is located partly on the railway company's right-of-way and runs partly over public domain to cut out detours.

A profile of the 440-mile section of railway from Harlowton to Avery is shown in Fig. 8. There are fourteen sub-stations for the 440 miles from Harlowton to Avery, and these are shown in the figure. The distance between sub-stations ranges from 18 to 43 miles, the average distance being 32.5 miles. (We have seen that the distance between the sub-stations on the Butte 2400-volt railway was 26 miles.) The section between Three Forks and Deer Lodge includes the crest of the line over the main range of the Rocky Mountains. West-bound trains have a 21-mile climb up a 2 per cent. grade, while east-bound trains must ascend 10 miles of 1.66 per cent. grade.

The sub-station equipment comprises oil-immersed three-phase transformers (for stepping down the pressure from 100,000 volts to 2300 volts) and motor-generator sets which convert the 2300-volt three-phase electricity into 3000-volt direct current. Each motor-generator set comprises a 60-cycle synchronous motor, direct connected to two 1500-volt direct-current generators. These two generators are connected in series to provide 3000 volts. The excitation for each set is supplied from two exciters, one at each end of the shaft. The motor-generator sets are of two sizes, the continuous ratings being respectively 1500 kw. and 2000 kw. Their two-hour ratings are respectively 2250 kw. and 3000 kw., and the generators are compound wound to maintain constant terminal pressure for all loads up to their two-hour rating. They also have five-minute ratings of three times their continuous rating. Thus we have for the two sizes—

	Kilowatts.	Kilowatts.
Continuous rating	1500	2000
Two-hour "	2250	3000
Five-minute "	4500	6000

The location and equipment of the fourteen sub-stations are given in the following table:—

Name of Sub-Station.	Distance from Avery in Miles.	Number of Step-Down Transformers.	Size of each Transformer in KV.A.	Total Capacity of Transformers in KV.A.	Number of Motor-Generator Sets.	Size of each Motor-Generator Set in KW.	Total Capacity of Motor-Generator Sets in KW.
Two Dot ..	426	2	2500	5000	2	2000	4000
Summit ..	392	2	2500	5000	2	2000	4000
Josephine ..	362	2	2500	5000	2	2000	4000
Eustis	332	2	2500	5000	2	2000	4000
Piedmont ..	289	3	1900	5700	3	1500	4500
Janney	262	3	1900	5700	3	1500	4500
Morel	228	2	2500	5000	2	2000	4000
Gold Creek ..	193	2	2500	5000	2	2000	4000
Ravena	160	2	2500	5000	2	2000	4000
Primrose ..	122	2	2500	5000	2	2000	4000
Tarkio	86	2	2500	5000	2	2000	4000
Drexel	47	2	2500	5000	2	2000	4000
East Portal ..	24	3	2500	7500	3	2000	6000
Avery	0	3	1900	5700	3	1500	4500

Total for fourteen sub-stations: 74,600 kv.a. of transformers; 59,500 kw. of motor generators.

It is seen from the above table that there is a total capacity of 74,600 kv.a. of transformers to supply the synchronous motors, as against 59,500 kw. in direct-current generators. Taking the over-all efficiency of the sets as 91 per cent., the input to the synchronous motors for a rated output of 59,500 kw. from the generators is 65,500 kw., and since the corresponding input is 74,600 kv.a., the machines may be operated with a power-factor of 0.88; that is to say, if the fields of the synchronous motors are sufficiently over-excited, the transformers will provide an incoming current which will lead with a power-factor of 0.88.

The forty-two locomotives each have a continuous rating of 3020 horse-power and weigh 250 British tons. A 250-ton St. Paul locomotive is thus 40 per cent. more powerful than two 72-ton Butte locomotives operated as a single machine. In addition to this, the St. Paul locomotives are equipped for regenerative braking for long periods on down-grades. The electrical equipment

* The author wishes to take this opportunity to express his thanks to Messrs. A. H. Armstrong and E. S. Johnson, who are closely associated with the electrification of the Chicago, Milwaukee and St. Paul Railway, for the assistance which they have given him in supplying the information embodied in the author's description of this undertaking. Reference should also be made to an article at page 683 of the *Railway Age Gazette* for October 15, 1915, entitled "Electrification of 440.5 miles of the St. Paul."

* For every foot of elevation, the potential energy in a British ton is 0.840 watt-hour. One acre-foot of water weighs 1220 British tons. Consequently, for every foot of elevation, an acre-foot of water represents 1.025 kw.-hour of potential energy. Assuming that the 400,000 acre-feet of water-storage in question has an average utilisable head of 70 ft., and that 50 per cent. of it can be delivered as electricity to consumers, then the total amount of electricity which thus can be made available is (400,000 × 1.025 × 70 × 0.50 =) 14.4 million kw.-hours.

is consequently very liberally designed and weighs 73 lb. per horse-power of continuous rating.

Of the forty-two locomotives, thirty are for freight service. Each motor's armature-shaft is fitted with an 18-tooth pinion at each end. These pinions engage with 82-tooth gears on the locomotive axle, the ratio of speed reduction thus being 4.56. The remaining twelve locomotives are for passenger service. These have 29-tooth pinions and 71-tooth gears, the ratio being 2.45. Except for this difference, and an additional weight of 18 British tons for steam-heating equipment, the passenger locomotives are identical with the freight locomotives. Six of the thirty freight locomotives also have the steam-heating equipment, and are thus available for hauling passenger trains.

The trolley is of the "double-wire catenary" construction, and consists of two 4/0 wires suspended from the same catenary, but by independent hangers. This interesting and very effective construction is difficult to illustrate. Above tangent track the two wires lie close together, and are not readily distinguished from one another; but on curves there is a little distance between the two wires at the points of suspension. The points of suspension of the one wire, by means of its hangers, are midway between the points of suspension of the other wire. This alternation continues right along the structure.

The locomotive's pantographs each carry a double-pan collector. By means of such a double-pan collector making sliding contact with two 4/0 trolley-wires, supported as above described, 2000 amperes can be satisfactorily collected at any speed up to 60 miles per hour. There will be no occasion to collect so great a current as 2000 amperes in the contemplated service. Each locomotive is fitted with two pantographs. The method of alternate suspension of the two trolley-wires has been found to provide an exceedingly smooth operation, with complete elimination of any tendency to flash at the points of suspension at any speed.

The leading dimensions and performance characteristics of the freight locomotive are as follow:—

Total weight	250 British tons
Weight—mechanical equipment	340,000 lb.
" electrical "	220,000 "
" on drivers	200 British tons
" on each guiding-truck	25 " "
Number of driving-axles	8
Weight per driving-axle	25 British tons
Number of motors	8
" guiding-trucks	2
" axles per guiding-truck	2
Weight on guiding-axle	12.5 British tons
Over-all length of locomotive	112 ft.
Rigid wheel-base	10 ft. 6 in.
Diameter of driving-wheels	52 in.
" guiding "	36 "
Total output of motors (continuous rating)	3020 horse-power
Tractive effort (continuous rating)	71,000 lb.
Speed at this tractive effort at 3000 volts	15.9 miles per hour
Per cent. which above tractive effort constitutes, of weight on drivers	15.8 per cent.

If we assume a train friction of 6 lb. per ton, then, when developing its rated tractive effort of 71,000 lb., the following are the complete train weights and the trailing loads which one of these 250-ton locomotives can draw up various grades. The speed will, in each case, be 15.9 miles per hour, and the load on the motors will be 3020 horse-power.

Grade.	Total Train Weight.	Trailing Load.
per cent.	British tons	British tons
0.5	4120	3870
1.0	2500	2250
2.0	1400	1150
3.0	970	720
4.0	740	490

On the assumption of equal frictional resistance of locomotive and load hauled, in pounds per ton, the efficiencies for these five cases are as given in the table in the next column.

The locomotive's characteristic curves at 3000 volts are drawn in Figs. 9, 10, 11, and 12. The eight motors are geared to the locomotive's driving-wheels, and each has a continuous rating of 378 horse-power at 1500 volts. They are permanently connected in series pairs, each pair using a pressure of 3000 volts for the parallel-running position. Each motor is cooled by the forced circulation of air through it from an external blower outfit.

Grade.	Efficiency of Electrical Equipment.	"Drivers-to Draw-Bar" Efficiency.	"Pantograph-Draw-Bar" Efficiency.
0.5	0.89	0.94	0.83
1.0	0.89	0.90	0.80
2.0	0.89	0.82	0.73
3.0	0.89	0.74	0.66
4.0	0.89	0.66	0.59

Fig. 9.

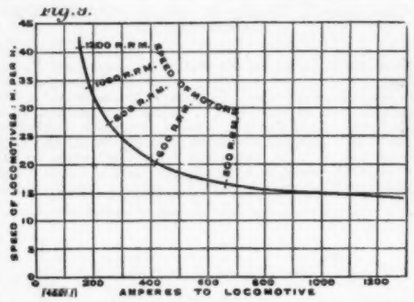


FIG. 9. SPEED-CURRENT CURVE OF CHICAGO, MILWAUKEE AND ST. PAUL 3000-VOLT GOODS LOCOMOTIVE. (Diameter of Driving-Wheels, 52 In.; Gear Ratio, 4.56.)

The passenger locomotive weighs 268 tons, and will haul a 700-ton trailing passenger train at a speed of 60 miles per hour on level track, and it will carry this train up all gradients of not over 1.5 per cent. For 2 per cent. grades the assistance of a pusher will be required. A 550-ton train can be hauled up a 2 per cent. grade by one of these 268-ton passenger locomotives without assistance.

The heaviest duty of the freight locomotive consists in drawing a trailing load of 2230 British tons from Lombard (see Fig. 8) to Summit over the Belt Mountains. The distance is 49 miles, the ruling grade is 1 per cent., and the average grade for the 49 miles is 0.7 per cent. The tractive effort for the average grade is

$$(22.4 \times 0.7 + 6) \times (2230 + 250 = 54{,}000 \text{ lb.}$$

From the characteristic curve in Fig. 11 we find the corresponding speed to be 16.5 miles per hour. The average output from the motor is—

$$\frac{16.5 \times 5280 \times 54.000}{60 \times 33{,}000} = 2380 \text{ h.p.}$$

The average current is 670 amperes. When this run is made without stops, it will take three hours to cover the 49 miles between Lombard and Summit. On the ruling grade of 1 per cent. the tractive effort required is 71,000 lb., and the corresponding speed and the output are 15.9 miles per hour and 3020 horse-power. The average consumption for this 49-mile run is—

$$\left(\frac{670 \times 3000 \times 3}{2480 \times 29} = \right) 49.5 \text{ watt-hours per ton-mile.}$$

Assuming 75 per cent. efficiency from the points where the electricity is delivered to the railway, the amount of electricity purchased is $\left(\frac{49.5}{0.75} = \right)$ 66 watt-hours per ton-mile. Since the price is 0.26d. per kw.-hour, the outlay for power is (0.26 × 0.066 =) 0.0172d. per ton-mile, or

$$(2230 + 250) \times 0.0172 = 43\text{d. per train-mile.}$$

The best steam-locomotive alternative consists in hauling such a train by a locomotive with 200 tons on drivers. Such a locomotive with loaded tender would weigh 330 tons. When hauling a 2230-ton trailing load on the average grade of 0.7 per cent. the speed will not exceed 8.3 miles per hour, or about half the speed of the electric locomotive. Exclusive of stops, the time required for the 49 miles would be 6 hours. The tractive effort on the 0.7 per cent. average grade is

$$(2230 + 330) \times (22.4 \times 0.7 + 6) = 55{,}500 \text{ lb.}$$

The output at the drivers is

$$\frac{55{,}500 \times 8.3 \times 5280}{60 \times 33{,}000} = 1230 \text{ h.p.}$$

This corresponds to $\left(\frac{1230}{0.75} = \right)$ 1640 indicated horse-power. If the locomotive burns lignite with a calorific value of 11,000 B.ThU. per pound, the consumption will be 4 lb. per indicated horse-power hour. The 49-mile run requires (1640 × 6.0 =) 9850 indicated horse-power hour. Consequently (exclusively of the consumption during stops) $\left(\frac{9850 \times 4.0}{2240} = \right)$ 17.5 tons of coal will be burned during the journey, or 2.92 tons (6550 lb.) per hour.

This rate is beyond the capacity of hand-firing, and requires a locomotive equipped with mechanical stokers. The fuel consumption will be

$$\left(\frac{17.5 \times 2240}{49} = \right) 800 \text{ lb. per locomotive-mile.}$$

The stops inherent to steam-locomotive operation will not be accompanied (as in the electric locomotive) with a complete cessation of fuel consumption. On the contrary, the fuel burned during stops will bring the consumption per locomotive-mile up to at least 900 lb. At 12s. per ton the fuel-cost will be

$$\frac{900 \times 12 \times 12}{2240} = 58\text{d. per train-mile,}$$

as against 43d. per train-mile for the electric locomotive. The 49-mile run forming the subject of this estimate represents the heaviest duty, and it will, for the purposes of a rough survey, be assumed that the average consumption of electricity and coal per locomotive-mile will, taken for the year, be only one-third of the amounts estimated for the 49-mile run.

While large Mallets can be bought for a matter of 24l.* per British ton, electric locomotives of the type under discussion cost fully three times as much, say at least 80l. per ton. On the other hand, the repairs of a 330-ton Mallet amount to a matter of at least 12d. per mile, as against not over 5.5d. per mile for the 250-ton electric locomotive. If we credit both locomotives with a 15-year life, crediting the electric locomotive with 35,000 miles per annum, and the steam locomotive with 25,000 miles per annum, and debiting both locomotives with 7d. per mile for wages of crew, the account stands—

—	Annual Outlay in Pounds Sterling.	
	Per 250-Ton Electric Locomotive.	Per 330-Ton Mallet Locomotive.
	£	£
I. Fuel and power	2080	2090
II. Wages of locomotive crews	1020	730
III. Repairs of locomotives	810	1250
IV. Interest (5 per cent.), taxes and insurance (3 per cent.) and amortisation (4.6 per cent.)	2400	950
Total of I.+II.+III.+IV.	6310	4950
Do. per locomotive-mile	43.3d.	47.5d.

* At page 1242 of vol. xxxii. (1913) of the Transactions of the American Institute of Electrical Engineers, Messrs. Hall and Welsh state:—"Also, the cost of 250-ton Mallets is given as 45,000 dols. The 300-ton Mallet mentioned above costs now approximately 33,500 dols., and the heaviest Mallet locomotives ever built (weighing 425 tons) cost slightly less than 44,000 dols. It is evident that the figure of 45,000 dols. is much too

Fig. 10.

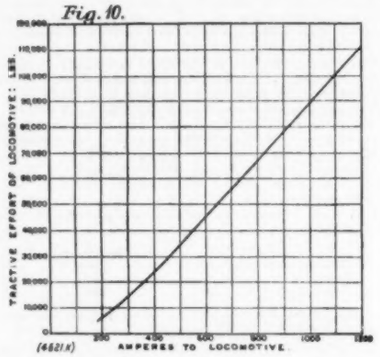


FIG. 10. TRACTIVE-EFFORT-CURRENT CURVE OF CHICAGO, MILWAUKEE AND ST. PAUL 3000-VOLT GOODS LOCOMOTIVE.

Fig. 11.

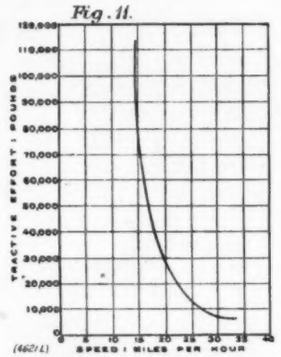


FIG. 11. TRACTIVE-EFFORT-SPEED CURVE OF CHICAGO, MILWAUKEE AND ST. PAUL 3000-VOLT GOODS LOCOMOTIVE.

Fig. 12.

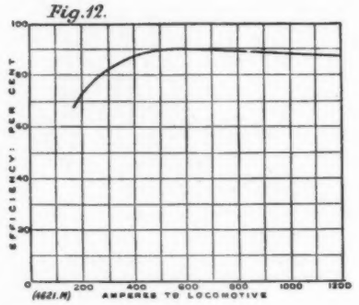
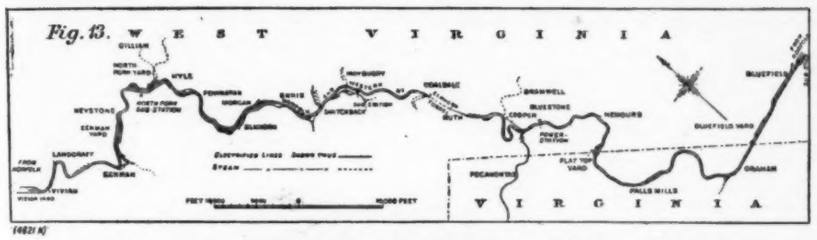


FIG. 12. EFFICIENCY-CURRENT CURVE OF CHICAGO, MILWAUKEE AND ST. PAUL 3000-VOLT GOODS LOCOMOTIVE.

For the above study, which is based on equal weights of train hauled, the saving in favour of the electric locomotive is of inconsiderable amount. In practice, however, advantage is taken of the inherent ability of hauling heavier trains with electric locomotives and at higher speeds. In both of these respects electric operations increases the capacity of a railroad and incidentally decreases the outlay for wages of engine crews and train crews. This has already been brought out in the analyses of the results actually obtained on the Butte, Anaconda and Pacific Railway.

Indeed, the Mallets actually employed on the Chicago, Milwaukee and St. Paul Railway are much smaller than that on which the above illustration is based, and cannot, even at their lower speed, handle the service for which the electric locomotives are adequate. A comparison between the St. Paul Mallets and the 250-ton electric freight locomotives is given in the following table:—

	Chicago, Milwaukee and St. Paul Mallet Locomotive.	Chicago, Milwaukee and St. Paul Electric Locomotive.
Total weight (in British tons)	348 (including tender)	250
Weight on drivers (in British tons)	145	200
Tractive effort which electric locomotive can develop for one hour, starting cold	—	34,400 lb.
Tractive effort which electric locomotive can develop continuously ..	—	71,000 ,,
Wheels per guiding truck	2	4
Weight per driving-axle (in British tons)	24.0	25.0
Total weight on one rigid-wheel-base truck ..	72.5	50.0



(4621 K)

FIG. 13. ELECTRIFIED DIVISION OF THE NORFOLK AND WESTERN RAILWAY.

From the above table we see that, although the weight of the electric locomotive is practically equal to the combined weight of steam locomotive and tender, it has a 38 per cent. greater weight on drivers, and consequently can, for a given limiting coefficient of adhesion, develop a 38 per cent. greater tractive effort. This gives it, for a 1 per cent. grade and for a coefficient of adhesion of 0.18 in both cases, and allowing 6 lb. per ton for friction, capacity to haul a train of (2850−250 =) 2600 British tons behind the draw-bar, as against a train of only (2050−250 =) 1800 British tons for the Mallet under the same conditions. The result is in favour of the electric locomotive to the extent of 44 per cent. (since $\frac{2600}{1800} = 1.44$) for these particular conditions. Even in these estimates the Mallet has not been debited with any greater friction than the electric locomotive, although some investigators have arrived at values of the order of over 30 lb. per ton for the resistance of Mallet locomotives.* Since the electric locomotive has guiding-trucks at both ends, there is no need for turntables, and the outlay for these, as also for stations for replenishing supplies of coal and water, is dispensed with.

Opinions of Relative Ruggedness of Steam and Electric Locomotives.—At page 294 of *The Electric Journal* for July, 1915, in the course of some comments on the Norfolk and Western electric locomotives (which are discussed elsewhere in this lecture), Mr. G. M. Eaton writes:—"The impression given by the locomotives as they pass, hauling their loads, is one of rugged simplicity and of fitness for handling the service. This picture is intensified, and is indelibly fixed on the minds of those fortunate enough to see the steam and the electrically-hauled trains in direct comparison, as has been possible during the period of changing over from steam to electric service. Three great Mallet steam locomotives, of most modern construction, labour past hauling their train up the grade at about 7 miles per hour. A little later come two electric locomotives hauling a train of identical make-up over the same grades and curves at twice the speed, and without apparent effort."

At page 830 of *The General Electric Review* for August, 1915, Mr. A. H. Armstrong, in alluding to the electric locomotives for the Chicago, Milwaukee and St. Paul Railroad, writes:—"For example, it has a capacity of 3600 horse-power for one hour, and even greater than this for short periods. The sustained tractive effort is 72,000 lb. at a speed of 15½ miles per hour at full sub-station line potential. Compare this with the Mallet engine of approximately the same weight now in operation on the St. Paul road, and we find that the Mallet has 76,200 lb. tractive effort, corresponding to 23.5 per cent. coefficient of adhesion, but those of you familiar with this beast of burden know that it toils painfully at speeds seldom exceeding 7 to 10 miles per hour when operating at its full hauling capacity. It is in this matter of higher speed for the same tractive effort that the electric locomotive excels."

At page 1889 of the Proceedings of the American Institute of Electrical Engineers for August, 1915, Mr. W. S. Murray writes:—"The steam locomotive has lived a useful life of eighty years. This is not a prediction that it will not live many more. Even in the clothes of its mechanical ruggedness it is not difficult to conceive of its having once been a pretty delicate machine, deserving of a very great deal of care and attention. The electric locomotive was born of even a more delicate nature, and while its ruggedness is increasing, it can never possibly be the great mechanical brute that our high-powered steam locomotives may be typified as being to-day."

It is impossible to reconcile Mr. Murray's conception of the electric locomotive as a "delicate" machine and of the steam locomotive as a machine characterised by "mechanical ruggedness" with the established fact that "repairs" per locomotive-mile are less than half as much for an electric locomotive as for a steam locomotive for the same service.

The Pusher Service for Heavy Grades.—On those sections of the line where the grade is much in excess of 1 per cent. for any considerable distance a second 250-ton electric locomotive will be employed as a pusher. On the 440 miles between Harlowton and Avery there are only two points where, with electric operation, a pusher-locomotive will be required, whereas with steam-locomotive operation there are many such points. At the ends of the pusher divisions sidings are provided, permitting the pusher-locomotive to be transferred to the head of the train, where it supplements the other locomotive in providing regenerative braking on the down grade.

Although the control permits of operating two 250-ton locomotives together under the control of one engineer by means of the multiple-unit-control system, this can only be done when the two locomotives are either pushing at the rear end of the train or else being pushed by the train on down grades, for the two locomotives are capable (with a coefficient of adhesion of 0.25) of exerting a tractive effort of 100 tons—an amount decidedly in excess of the strength of the draught rigging.

Regenerative Braking.—The electric service on the Chicago, Milwaukee and St. Paul Railway will include the feature of regenerative braking.

In a paper by the author, entitled "2400-Volt Railway Electrification," and published at page 1149 of vol. xxxii. (1913) of the Transactions of the American Institute of Electrical Engineers, estimates were made relating to the electrification of a hypothetical 96-mile single-track mountain-grade division of a main-line railway. The trains ascended to an altitude of 3800 ft. in 48 miles and returned to the original level in the remaining 48 miles, the average gradient thus being 1.5 per cent. It was assumed that the ruling gradient was 2.2 per cent. Trains of weights up to 1600 British tons were to be hauled by electric locomotives over this division, the average speed between stops being 12 miles per hour. For standard equipments with series motors and with no provision for regenerative braking the costs per locomotive-mile as compared with steam-locomotive haulage were worked out. Were regenerative control to be employed during the 48-mile descent, the estimates would be as follow:—

The altitude attained by the train is 3800 ft. In descending there is given up by a train with a weight of 1600 British tons behind the draw-bar of two 143-ton locomotives—

$$3800 \times (1600 + 2 \times 143) \times 2240 = 16{,}100{,}000{,}000 \text{ ft.-lb.}$$

of energy.

There is required for friction—

$$(1600 + 2 \times 143) \times 8 \times 5280 \times 48 = 4{,}300{,}000{,}000 \text{ ft.-lb.}$$

After deducting the amount required for friction, there remains 11,800,000,000 ft.-lb., or 4450 kw.-hours (since 1 kw.-hour = 2,659,000 ft.-lb.). This energy can be applied to drive the motors as dynamos and return most of it, in the form of electricity, to the distribution system. The author was associated with successful tests of this kind (although on a city tramcar) made at Newcastle in 1901. Careful measurements were made in the Newcastle tests, and for regeneration on long descents high efficiency was obtained.

Mechanical brakes will still be provided in the case we are considering, in order to have duplicate means of controlling the train, but these will be regarded as a reserve, and will not be employed except at the very lowest speeds and to hold the train at rest on grades. Let us take the efficiency of regeneration at 68 per cent. Then

$$0.68 \times 4450 = 3000 \text{ kw.-hours}$$

of electricity will be sent back into the line during the 48-mile descent.

It had been estimated in the author's paper that without regenerative control the consumption of the 1600-ton train in making the 96-mile journey would be 11,700 kw.-hours. With regenerative braking, and employing the conservative estimate above set forth, the consumption is reduced to

$$11{,}700 - 3000 = 8700 \text{ kw.-hours.}$$

By similar estimates of the consumption of electricity for the entire traffic occurring on this 96-mile division in one year, a total annual input to the sub-stations of 107 million kw.-hours is estimated, as against 144 million kw.-hours per annum without regeneration. The price paid for the electricity is 0.336d. per kilowatt-hour in both cases. Forty-eight locomotives, each averaging 27,200 miles per annum, are estimated to be required to handle the traffic. The total annual outlay for electricity, and also the annual outlay per locomotive and per locomotive-mile, without and with regenerative control, work out as follow:—

Annual Outlay for Electricity.	Without Regenerative Control.	With Regenerative Control.
Total	£200,000	£149,000
Per locomotive	£4,160	£3,100
Per locomotive-mile	36.8d.	27.4d.

The relative operating costs for the steam locomotive and for the two cases of the electric locomotive—*i.e.*, without and with the allowance for regeneration, arrived at in the preceding calculation—are shown in the following table, which is based on electricity at 0.336d. per kilowatt-hour, and lignite with a calorific value of 11,000 B.Th.U. per lb. at 11s. per British ton.

—	Operating Expenses in Pence per Locomotive-Mile.		
	Steam Locomotive.	Electric Locomotive.	
		Without Regenerative Control.	With Regenerative Control.
Fuel	30.7	—	—
Electricity	—	36.8	27.6
Repairs	9.6	2.7	2.7
Wages	9.0	9.1	9.1
Engine-house expenses	1.7	—	—
Lubricants	0.4	0.2	0.2
Stores	0.3	0.2	0.2
Total	51.7	49.0	9.8

It was shown in the paper that for 1600 British tons behind the draw-bar there would be required three 220-British-ton steam locomotives or two 143-British-ton electric locomotives. Consequently the operating expenses (for locomotives) per train-mile work out as follow:

—	Operating Expenses in Pence per Train-Mile.		
	With Three 220-Ton Steam Locomotives.	With Two 143-Ton Electric Locomotives.	
		Without Regenerative Control.	With Regenerative Control.
Fuel	92.1	—	—
Electricity	—	73.6	55.2
Repairs	28.8	5.4	5.4
Wages	27.0	18.2	18.2
Engine-house expenses	5.1	—	—
Lubricants	1.2	0.4	0.4
Stores	0.9	0.4	0.4
Total	155.1	98.0	79.6

For mountain-grade applications, such as that employed in the above example and for sparse traffic in general, certain important advantages attending the application of regenerative control to a dense traffic are not obtained, and although the saving in the amount of electricity consumed may often be notable, as shown by the above results, a main consideration in adopting regenerative control relates to the lesser wear of the wheels, the brake-shoes, and the brake-rigging. With mechanical braking, the speed at which a heavy freight train may be taken down mountain grades is often limited by the permissible heating of the brake-shoes. With regenerative braking, the limit is raised to that imposed by other factors, such as the safe speed imposed by curves or by the construction of the rolling-stock or permanent way.

With a dense traffic, the employment of regenerative braking introduces savings of another character as the result of the interchange of current between neighbouring trains. Ascending or accelerating trains draw a part of their power directly from neighbouring descending or stopping trains. It is analogous to the installation of many additional sub-stations distributed along the route.

high." Translating these figures, we have—

$$\text{Cost of 268-British-ton Mallet} = \frac{33{,}500}{5 \times 268} = 25d. \text{ per ton.}$$

$$\text{Cost of 380-British-ton Mallet} = \frac{44{,}000}{5 \times 380} = 23d. \text{ per ton.}$$

* See page 1308 of Cary T. Hutchinson's paper, entitled "The Electric System of the Great Northern Railroad Company at Cascade Tunnel," published at page 1281 of vol. xxviii. (1909) of the Transactions of the American Institute of Electrical Engineers.

With electricity thus interchanged between neighbouring ascending and descending trains, there is associated a lower loss in the distributing system than is the case when the electricity is sent over a considerable distance from the sub-stations to the train. Furthermore, the sub-stations are relieved of a part of the burden, and the load-factor of the remaining part is increased. Thus the sub-stations are shielded from the peaks of load, and need not be equipped with motor-generators of so great a short-time rating. Indeed, their continuous rating may also be less, since the average output is decreased when supplying trains with regenerative equipment, except in so far as such equipment will be heavier and will increase the total weight moved. The energy efficiency of these motor generators will be higher with the more uniform load. These conclusions only hold good for a dense traffic. For a traffic of so sparse a character that on some occasions the load comprises only one train, there can be no equalising out between trains, and this will also be the case with several trains per sub-station if all the trains are simultaneously absorbing power from the sub-station. Consequently the maximum of advantage from the employment of regeneration, so far as regards decreased outlay for power, will be obtained with a dense, well-distributed traffic and with the use of so high a working pressure as to permit of locating the sub-stations long distances from one another. While on the Chicago, Milwaukee and St. Paul Railway the trains will be relatively infrequent, it is nevertheless considered that the advantages obtainable by incorporating the regenerative feature in the locomotive equipment are amply sufficient. These advantages relate chiefly to emancipation from the limitations of mechanical brakes.

The modern motor for locomotive equipments is provided with forced ventilation and is much lighter for a given continuous output than were the earlier self-cooled motors. An important feature affecting its appropriateness for regenerative braking is that its continuous output is well up towards the output of which it is capable for one or two hours for a given temperature rise. Consequently it is not necessary to greatly increase its weight in order that it shall be able to perform as a generator on down grades and when decelerating the train. This was not the case with the railway motor of a dozen years ago. At that time the continuous output for a given temperature rise was rarely as much as half of the output of which it was capable for one hour for the same temperature rise. Under those conditions it was essential to successful regeneration to employ very much heavier equipment. The increased weight and cost of such an equipment, had it been provided, would have gone far towards offsetting the decreased energy-consumption per ton-mile obtained in virtue of regeneration. Moreover, it would have been necessary to take into account, not only the increased first cost of these heavy equipments, but also the increased depreciation associated with this larger outlay.

If the subject had been thoroughly analysed in those days, it would have been found that in most cases the increased weights of the electric equipment would have occasioned a 10 per cent. or, in some cases, even a 15 per cent. increase in the total weight of the car or train. Consequently a 20 per cent. decrease in the energy-consumption expressed in watt-hours per ton-mile obtained in virtue of regeneration would have left an insignificant margin for net decrease in energy-consumption per car-mile or per train-mile. But with modern methods of intensive ventilation regenerative-control equipments can be built with but moderate increase in weight, and still operate within approved temperature limits, notwithstanding the performance of the double function of motoring and generating.

From the considerations which have been set forth the appropriateness of regenerative control for a dense traffic such as systems of urban and suburban trains should be evident when reconsidered in the light of the characteristics of modern railway equipments. The capital cost for generating-station, for transmission-line, and for sub-stations, should be notably less when the rolling stock is equipped with regenerative-control apparatus than would otherwise be the case. We thus have not only the decreased consumption at the train per ton-mile, but we also have the decreased interest and depreciation outlays for sub-stations, transmission-line, and generating-station. For instance, if there were required for the operation of an electric railway with a dense traffic an output from the generating-station of, say, 100,000 kw.-hours per annum, then, while for an ordinary system without regenerative control it would be necessary to instal fully 25,000 kw. rated capacity of generating sets, this aggregate capacity would, with regenerative control, be materially reduced, say, to 22,500 kw. rated capacity. The percentage decrease in the rated capacity required in the sub-stations would be of at least equal amount, and savings would also be effected in the transmission cables and in the distributing system between the sub-stations and the contact conductors. Added to these capital savings, there is the further operating saving resulting from the reduced consumption at the train.

It will be recognised from a consideration of the various factors entering into the problem that it requires very careful estimating to arrive in any particular case at a fair quantitative comparison of two systems, the one with and the other without the regenerative feature. Different results will be obtained in different cases. For a level service, the shorter the distance between stops and the higher the schedule speed, the more appropriate does the regenerative system become. For other than a level service, obviously, the more irregular the profile of the route, the more appropriate is regenerative control.*

(*To be continued.*)

* On December 9 Mr. Aspinall received the following cable from Mr. Hobart:—"On occasion my James Forrest lecture, please announce that on St. Paul electrification 2500 British-ton trailing load, 12 per cent. more than guarantee has been hauled up the 20-mile grade Piedmont to Donald, containing 2 per cent. grades, by two 250-ton 3000-volt electric locomotives, descent successfully controlled regeneratively, returning electricity into 100,000-volt transmission system. Official tests now taking place, to be followed immediately by regular electrical services on 113-mile division between Threeforks and Deerlodge."

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data taken from the *Board of Trade Journal* on several colonial and foreign engineering projects. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Australia: The *New South Wales Government Gazette* publishes official notices authorising the construction of (1) the second part of the railway from Dubbo to Werris Creek, covering a distance of about 17 miles, and (2) sections of the Condobolin-Broken Hill Railway, representing a total distance of about 60 miles.

Spain: The *Boletin de las Cámaras de Comercio*, Madrid, states that, according to statistics published by the Union Eléctrica Española, there are fifty hydro-electric installations in Spain of over 800 horse-power. The combined force of these installations represents 1,008,876 horse-power, of which 266,576 horse-power are now in exploitation. There are twenty-one installations of from 300 to 800 horse-power, the total power of which is 10,243 horse-power, all in use. The number of enterprises representing less than 300 horse-power is thirty-nine. It is stated that as there is an increasing number of factories, especially flour-mills, using hydraulic power not electrically transformed, the total water-power at present raised throughout the country represents over 1,000,000 horse-power, while the Spanish Electrical Union calculates that the water courses of the country are capable of yielding up to 6,000,000 horse-power. The *Gaceta de Madrid* contains the list, published annually, of the various classes of material which may be required by Spanish Government departments, and in the supply of which foreign competition will be permitted during 1916. Among the important items are the following:—Foreign timbers; bitumen; crude petroleum; coal for naval purposes, including anthracite, specified kinds of manufactured steel and wire; steel rails exceeding 50 kg. per lineal metre; metal chains; tubes and cables; anchors; tin, nickel, aluminium, platinum, bronze and copper goods; steam-turbines; gas-engines exceeding 300 horse-power; steam-boilers; dredgers; tools; metal-testing machines; machines connected with the tobacco, printing, lithographic, quarrying, &c., industries; weighing-machines; bicycles; electrical laboratory apparatus; electrical measuring instruments; telegraph and telephone appliances; electric search-lights; submarine cables; electric lighting accessories and arc-lamps; electric-generating machines; gas-lighting appliances for railway carriages; fire-extinguishing and life-saving appliances; munitions of war, such as explosives, shells, ammunition, pistols, as well as arsenal machinery; aeroplanes; scientific instruments; maps and atlases; drawing paper and models; marble and special glass; sanitary and drainage appliances; ventilating and disinfecting apparatus; medical and surgical appliances; lighthouse accessories; chemical products; linoleum; and musical instruments. The *Gaceta* of December 30 notifies that tenders will be received, within a period of three months from that date, by the Municipality of Seville, for the installation of plant and equipment in the new slaughter-house in that city. The conditions of contract contain clauses to the effect that at the first competition the materials to be used will be confined, with certain exceptions, to products of Spanish manufacture, but that, in the event of no decision being arrived at, a second competition, in which foreign products may be accepted, will then take place. In the latter event Spanish products will have a 10 per cent. margin of preference over foreign. The *Gaceta* also publishes a notice, issued by the Ministerio de Fomento, granting permission to Don Justo Calcedo to utilise, at the rate of 10,000 litres (2200 gallons) per second, the waters of the River Ebro in the district of Miranda for industrial purposes, and conceding to him the necessary land on which to construct a power-station, &c. The works must be commenced within a period of six months from the date of the concession and completed within two years.

Colombia: The *Diario Oficial*, Bogotá, publishes a Law empowering the Junta Central de Higiene to undertake the construction of a sanitary station in the port of Buenaventura similar to the existing station at Santa Marta. For this purpose the sum of 20,000 pesos gold (4000*l.*) is to be included in the National Estimates each year until the station is completed. The same Law also allots the sum of 10,000 pesos gold (2000*l.*) for the completion of sanitary buildings, for the bacteriological laboratory, and for the construction of a wharf at the sanitary station of Santa Marta.

AGRICULTURAL MACHINERY.—There was a very sharp contraction last year in the external demand for British agricultural machinery. This was largely due to the collapse of the central European markets, as in peaceful times British implement firms have developed valuable connections in Austria, Hungary, and Germany; the Russian demand has also not been without importance.

CATALOGUES.

Vacuum Cleaners.—The Sturtevant Engineering Company, Limited, of 147, Queen Victoria-street, E.C., have sent us a copy of a pamphlet illustrating and describing their turbine vacuum cleaning apparatus, which is suitable for use in all kinds of buildings, railway carriages, tramcars, &c. For large buildings stationary plants, comprising a multi-stage fan driven by an electric motor, are usually installed in the basement, and pipes, with suitable connections for the cleaning-nozzles, are run to all parts of the building; a dust-separator is, of course, provided near the inlet to the fan. These plants are made in five standard sizes of from 2 to 12 horse-power, and the larger sizes are capable of keeping five to eight operators employed simultaneously; larger plants can, however, be supplied if necessary. Portable cleaners, ranging from 6 to ½ horse-power are also made, the larger sizes for cleaning railway carriages, warehouses, workshops, and other buildings, and the smaller sizes for domestic use. In all cases the machines depend for their action on the exhaustion of a large volume of air at a low vacuum, which usually ranges from ½ in. to 2½ in. of mercury, and rarely exceeds 3 in. This enables large nozzles to be used, and large nozzles allow the carpet to lift slightly from the floor, so that the carpet bends and the pile opens out, and the dirt which accumulates at the bottom of the pile is all removed. It is also stated that higher vacua tend to damage the fabrics being cleaned.

Scherzer Rolling-Lift Bridges.—An interesting and attractive booklet briefly describing the inception, development, and use of Scherzer rolling-lift bridges has reached us from the Scherzer Rolling-Lift Bridge Company, of Monadnock Block, Chicago, U.S.A. The general principles of these bridges are clearly explained in the booklet, but we do not propose to deal with them here, as we have illustrated and described several examples in previous volumes, and the principles are now familiar to most engineers. It is interesting to note, however, that the first Scherzer bridge was constructed to carry the Metropolitan Elevated Railroad over the Chicago River at Chicago, where the limited right of way between existing swing-bridges precluded the use of a horizontally-moving bridge of the requisite span. Vertically-moving bridges of all types then known, including a reproduction of the Tower Bridge, were suggested and abandoned as failing to meet all requirements. William Scherzer, a consulting engineer of Chicago, eventually solved the problem with his rolling-lift design, and although he did not live to see its completion, the structure has now been in satisfactory service for over twenty years. During this period an average of 1500 trains daily have passed over the bridge, and no delays to railroad or river traffic have been recorded. Since that time some hundreds of bridges have been designed by the present company, which was formed soon after the death of William Scherzer, to develop the principles of the design and place them before the public on a business basis. Railway and road bridges with spans varying from 29 ft. to 310 ft., and ranging from 9 ft. to 130 ft. in width, have been built to their designs to meet widely varying requirements in many different parts of the world. No departure from the main principles of the original design has been found necessary, though, of course, many improvements have been made in details. For instance, the counterweight is now made of concrete, weighted, if necessary, by the addition of scrap-iron to the aggregate, instead of cast iron, as originally employed. The operating strut formerly used to roll the bridge backwards and upwards has been done away with, and the movement is now effected by means of pinions gearing with fixed racks placed parallel with the rolling track at the level of the centre of the segmental roller; the machinery is all carried on the bridge itself. Improvements have also been made in the design of the track and segmental roller, machined-steel castings now being used for the bearing surfaces instead of rolled-steel plates. The booklet gives a partial list of Scherzer bridges completed, or under construction, in different parts of the world, including ten in Great Britain and Ireland. Several examples are illustrated by means of excellent half-tone engravings, and the whole character of the booklet is highly creditable to those concerned with its production.

GERMAN CHEMICAL INDUSTRY IN 1915.—Though the rise and fall of company dividends are not an unfailing barometer of the state of a trade, the fall of dividends means something. During 1915 the dividends of all the big German chemical manufactories went down considerably, from 28 per cent. (in the previous year) to 19 per cent. in the case both of the Badische Anilin Fabrik and the Elberfeld Farbenfabriken, and from 30 to 20 per cent. in the case of the Höchster Farbwerke (which make the famous specialities of the late Professor Ehrlich); the Chemische Fabrik F. Schering paid 10 instead of 15 per cent., Th. Goldschmidt-Essen 8 instead of 12 per cent. But, the *Chemiker Zeitung* points out, these figures, if considered alone, would still give far too rosy a picture. Many chemical-trade firms did not pay any dividend at all. The same applies to one-third of the twenty-five cement works, to five out of ten big paper and cellulose works, and to many glass, porcelain, and earthenware works. Potash firms also did badly. On the other hand, the lignite and gas industries, also the starch and linoleum industries had little ground for complaint. In many works, no doubt, the profits—held over for the present and not yet noticed in the balance-sheets—made in the departments engaged in war supply balanced the losses of the other departments; but the general outlook was not a favourable one.